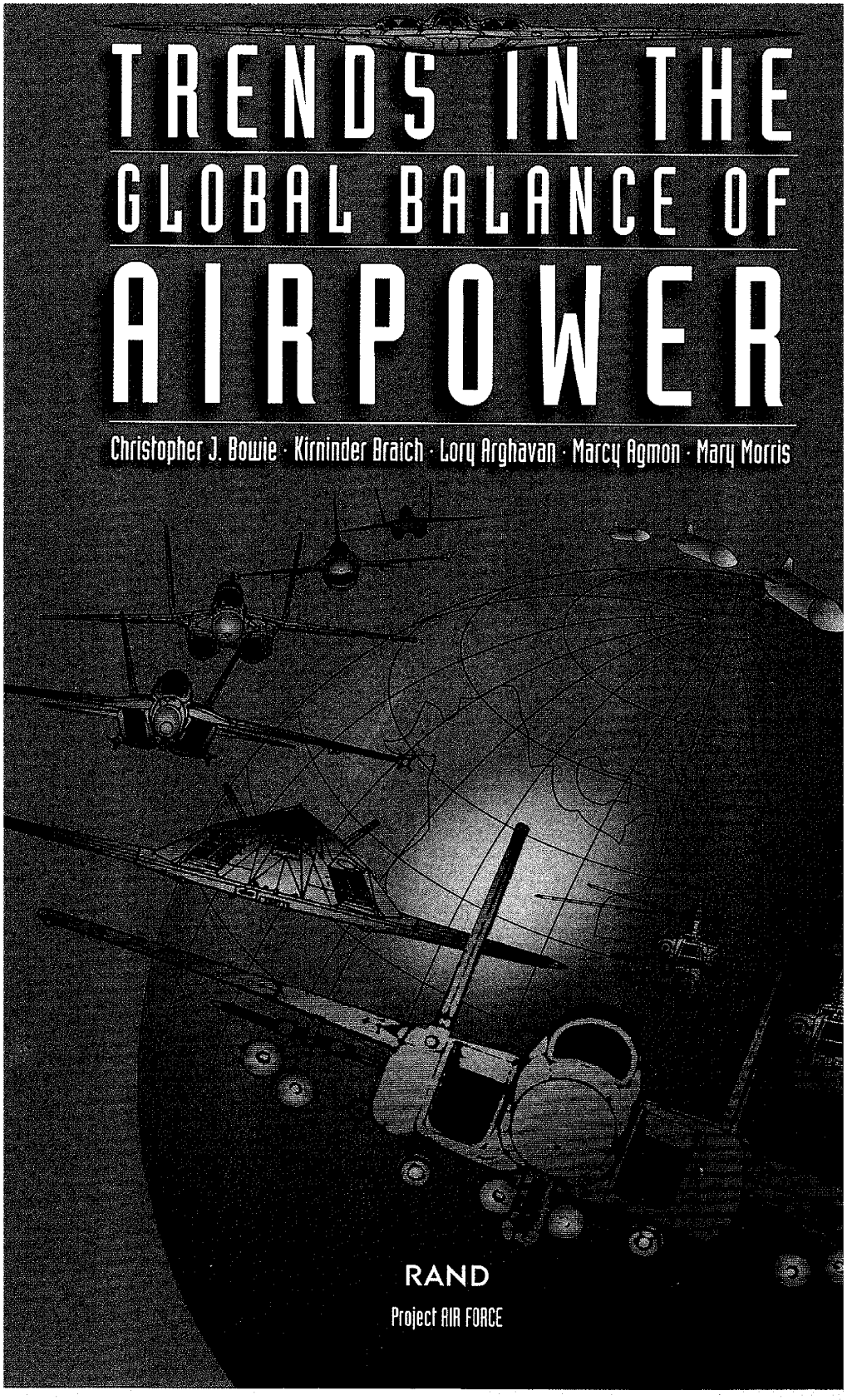
TRENDS IN THE GLOBAL BALANCE OF AIRPOWER

Christopher J. Bowie · Kirninder Braich · Lory Arghavan · Marcy Agmon · Mary Morris



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Project AIR FORCE

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Christopher J. Bowie · Kirninder Braich
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Prepared for the United States Air Force

RAND

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The research reported here was sponsored by the United States Air Force under Contract F49620-91-C-0003. Further information may be obtained from the Strategic Planning Division, Directorate of Plans, Hq USAF.

Library of Congress Cataloging in Publication Data

Trends in the global balance of airpower / Christopher J. Bowie . . . [et al.].
p. cm.
"Sponsored by the United States Air Force."
"MR-478/1-AF."
Includes bibliographical references.
ISBN 0-8330-1601-6 (alk. paper)
1. Air power. 2. Air forces. 3. United States. Air Force.
I. Bowie, Christopher J., 1954– . II. RAND. III. United States. Air Force.
UG630.T72 1995
358—dc20 94-42440
CIP

Cover Design: Peter Soriano

Published 1995 by RAND
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
RAND URL: http://www.rand.org/
To order RAND documents or to obtain additional information, contact
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Internet: order@rand.org.

PREFACE

The 1991 Gulf War took place on a global stage. Television images of the conflict were seen throughout the planet—and Gulf War analyses continue to form the subject of ongoing debates in the security and military policy communities of the world. These analyses are critical to understanding the character of future conflicts. The plans developed in reaction to these analyses will form the basis for future strategies, operational concepts, and the procurement of new equipment; these elements in turn will help define future war. For the United States to prepare for future combat, it must have analysis of what strategies and force elements its potential foes (and allies) may choose to employ.

This report takes a first step toward addressing this critical issue. The Gulf conflict was a highly successful joint campaign. But it was also a campaign in which airpower—in the form of aircraft, helicopters, surface-to-air missiles, cruise missiles, and ballistic missiles—played a far more prominent role in the coalition victory than it had in past conflicts. Moreover, official U.S. pronouncements have highlighted the role of U.S. sea-based and land-based airpower in supporting U.S. national military strategy for the post–Cold War world.

One obvious response that other nations might make—particularly nations that might come in conflict with the United States—would be to build or modernize their own airpower capabilities in order to stalemate U.S. airpower. This report's objective is to provide a perspective on the capabilities of various regional powers to challenge the United States and its allies in terms of airpower—particularly fixed-wing airpower—over the next ten to twenty years.

This report provides a broad overview of trends in the global balance of airpower. The research was sponsored by the Director of Plans, Headquarters, United States Air Force. The research was conducted in Project AIR FORCE's Strategy, Doctrine, and Force Structure Program, which is directed by Dr. Zalmay Khalilzad. This report provides the main findings of our analysis. A companion document, MR-478/2-AF, provides specific details on the data and supporting analyses employed in this report.

PROJECT AIR FORCE

Project AIR FORCE, a division of RAND, is the Air Force federally funded research and development center (FFRDC) for studies and analyses. It provides the Air Force with independent analyses of policy alternatives affecting the development, employment, combat readiness, and support of current and future aerospace forces. Research is being performed in three programs: Strategy, Doctrine, and Force Structure; Force Modernization and Employment; and Resource Management and System Acquisition.

Project AIR FORCE is operated under Contract F49620-91-C-0003 between the Air Force and RAND.

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SUMMARY

The end of the Cold War era has introduced new and significant challenges for U.S. military forces. The focus of U.S. national military strategy has shifted from the threat to U.S. interests posed by the former Soviet Union to those posed by regional powers. As laid out in the Department of Defense's recent "Bottom-Up Review," the vast majority of U.S. defense resources will be devoted to raising and equipping forces to fight major theater conflicts against potential regional foes.

Given the uncertainties of planning for a future security environment that promises to be unstable and unpredictable, the United States plans to maintain a robust joint force structure to help protect its vital interests around the world. Each Service has unique attributes, and the challenge facing planners is to maintain the appropriate balance so that key capabilities and assets are available when needed. But within this joint context, the airpower forces provided by the armed services—in the form of fixed-wing aircraft, helicopters, surface-to-air missiles, cruise missiles, and ballistic missiles—are receiving particular prominence for a variety of reasons:

- Airpower played a very significant role in the recent Gulf campaign. The implications of that role have not been lost on other powers.
- In the wake of the Gulf War, the role of airpower in U.S. security strategy has been highlighted prominently in official documents, speeches, and congressional testimony.

- The efficient employment of joint forces, while minimizing U.S. and allied casualties, requires the United States to gain control of the air.
- In many circumstances, airpower permits the application of military power while minimizing the risk to U.S. personnel.
- Planned investments in airpower forces—particularly helicopters, cruise and ballistic missiles, and fixed-wing aircraft—will form a substantial portion of the nation's future procurement spending.

The newfound prominence accorded to U.S. airpower, however, should sound a note of caution. In the current unstable and uncertain environment, the future leverage of U.S. airpower is dependent not only upon decisions taken by the United States, but also upon those made by other powers. One obvious response that other nations may make—particularly nations that might come in conflict with the United States—would be to build or modernize their own airpower capabilities in order to stalemate U.S. airpower. In such an event, U.S. strategy would be severely undermined. This report's objective is to assess the capabilities of various regional powers to challenge the United States in terms of airpower—particularly fixed-wing airpower—over the next ten to twenty years.

INITIAL PERSPECTIVES ON THE GLOBAL AIRPOWER BALANCE

We took a broad view of airpower: fixed-wing aircraft, helicopters, surface-to-air missiles (SAMs), cruise missiles, and ballistic missiles. Our primary metric was the inventories of these systems maintained by the world's powers. This is admittedly an imperfect metric, but it can yield important insights when analyzed carefully and viewed in the appropriate context.[1]

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[1]The true potential of a nation's airpower, of course, rests on other elements: such key issues as command, control, and surveillance capabilities and such intangibles as skilled and trained personnel. But airpower forces are equipment-intensive. Without vehicles that fly through the medium of the air, a nation does not possess airpower forces. Accordingly, analysis of inventories can shed some useful light on a nation's potential airpower capabilities.

The inventory data reveal that most of the world's powers—and the United States in particular—have spent more resources on fixed-wing aviation than on other forms of airpower. Fixed-wing aviation will also remain the combat backbone of U.S. airpower forces for many years to come and accordingly formed the primary focus of this analysis. But planners and strategists must be careful to consider other forms of airpower when they look at the future balance, and we would like to offer the following observations.

SAMs

The potential role of SAMs must figure prominently in U.S. planning. These weapons can dispute control of the air and can play an important part in the airpower balance. The data to date indicate that few nations have placed a heavy emphasis on SAMs to defend their airspace. Moreover, these systems have fared poorly in recent combat operations (such as the 1982 Israeli operation against Syrian SAMs and the 1991 Gulf War). But the potential of these systems means that they bear careful watching. The ongoing proliferation of man-portable SAMs combined with anti-aircraft gun defenses have, as illustrated by the Gulf War, reduced the capability of fixed-wing aircraft to operate at low altitudes over defended areas and maintain acceptable levels of attrition. Suppressing these widespread systems does not appear feasible. Because U.S. strategy hinges on employing fixed-wing aircraft to penetrate and exploit enemy airspace, the potential for nations to deny the medium and high altitudes by emphasizing more capable surface-based defenses bears careful watching and the adoption of appropriate counters (such as stealth, suppression systems, and new operational concepts).

Ballistic and Cruise Missiles

Our analysis illustrates that ballistic and cruise missiles appear particularly suitable as delivery vehicles for weapons of mass destruction and as terror weapons. For developing nations, conventionally armed missiles offer a means to strike deep into an adversary's territory with greater chances of success than strikes by fixed-wing aviation (particularly if opposed by U.S. airpower). For sustained conventional operations, however, missiles do not seem to be as cost-effective as fixed-wing aircraft. Moreover, ballistic and cruise

missiles suffer from operational constraints. For example, their capabilities to deal with mobile targets, such as maneuvering ground forces, will remain poor for some time. In conventional operations, cruise and ballistic missiles appear best suited to exact opportunity costs (such as forcing opponents to develop defenses) and to supplement fixed-wing airpower in conducting attacks.

Helicopters

The United States owns about a third of the planet's total military helicopter force and thus enjoys a dominant position in the rotary-winged balance. But that balance does not seem an especially vital element of the overall airpower balance. Although helicopters can conduct an increasingly important set of military operations, they are poorly suited to dispute control of the air and would not fare well when confronted with capable fixed-wing combat forces. An adversary that increased investment in rotary-winged systems would thus not improve its position relative to U.S. airpower.

THE CURRENT FIXED-WING BALANCE

The United States—and its traditional allies—have long emphasized fixed-wing airpower and have earnestly sought to increase the potential of these systems and understand their most effective employment. In the 1970s and 1980s, the United States made a massive investment in airpower. That investment has now placed the United States in a commanding position in terms of the global fixed-wing balance. U.S. land- and sea-based forces feature:

- A large and modern fighter force. Comparing planned U.S. airpower expeditionary forces to the airpower forces of regional powers reveals that the United States should enjoy an advantage in quantity and quality of equipment over the short term.
- A high ratio of support aircraft to combat aircraft. Moreover, U.S. support aircraft (such as tankers, airlifters, maritime patrol, surveillance assets, and the like) tend to be longer-ranged and more capable than those of other nations. These aircraft provide U.S. combat forces with greater reach, flexibility, and effectiveness.

THE FUTURE FIXED-WING BALANCE

The analysis indicates that U.S. prospects to maintain these advantages over the longer term are extremely good. Airpower is a capital-intensive form of military power. The U.S. airpower weapon that has emerged from the Cold War can be maintained and improved at a moderate cost (at least in relative terms compared to other regional powers) due to the large size of the U.S. economy and the modern force structure currently in place (which acts to reduce replacement requirements). In short, the United States appears capable of gaining and exploiting control of the air in a theater conflict for the foreseeable future, provided forces are sustained at planned levels and prudent modernization is conducted.

The long-term ability of the United States to maintain this commanding posture seems even stronger when one examines the prospects of other global airpower forces. We first looked at the two other largest airpowers—the former Soviet Union and China—and then turned our attention to the airpower prospects of other smaller regional powers. The analysis illustrates the following:

- The airpower forces maintained by the former Soviet Union have fragmented, and their recovery will take many years. In particular, the poor economic outlook for Russia and the various republics should limit the potential of their airpower forces for at least a decade or more.
- The size of China's future force is uncertain, but its modernization potential is poor. China faces a serious replacement problem as its current force ages and only obsolescent aircraft designs are currently available for manufacture as replacements. Developing the capability to manufacture more advanced aircraft will take a substantial period—at least a decade. Over the longer term, however, China could emerge as a more potent player in the airpower balance.
- Other regional airpower forces, particularly those developed by potential adversaries, tend to be small (compared to the planned U.S. airpower expeditionary force) and feature a high proportion of dated aircraft. Our analysis indicates that these forces are likely to shrink even further, and U.S. forces, once deployed, should continue to enjoy a *quantitative* advantage.

> Upgrades to existing forces and/or the acquisition of new aircraft will erode the U.S. *qualitative* edge when dealing with these forces. Smaller air forces, after all, could elect to focus on the air defense role with the aim of disrupting U.S. efforts to control the air. This approach could result in higher levels of attrition during combat unless the United States modernizes as well.

Advanced airpower forces are expensive. Attempts to shift the airpower balance would require massive investment by regional powers. This would require substantial growth in regional economies (something that cannot be assured and, in any case, would take many years to reach fruition) and/or a substantial shifting of the effort of national economies. Diverting an increasing proportion of national treasure to the military could undermine efforts to develop more robust economies. In addition, shifting spending patterns could upset the political balance of interservice power in many developing states (where ground forces are often the dominant institution).

The combination of a strong economy and national wealth has placed the United States in an extremely advantageous position in terms of the airpower balance. *The end result is that a U.S. air-dominant strategy is one that will prove extremely difficult to deal with "in kind."* Simply put, it is a strategy that favors the richer powers.

THE AIRPOWER BALANCE IN CONTEXT

The preceding has painted a picture of overwhelming dominance on the part of the United States in terms of the airpower balance—both at the close of the Cold War and for the foreseeable future. But dominance in the airpower balance does not mean that U.S. planners can be complacent. *Maintaining this powerful air weapon will require continued investment to ensure that potential opponents cannot inflict significant attrition, either through modernized air superiority forces or SAM-heavy defenses.*

Most importantly, we must consider the U.S. position in the airpower balance within the context of national strategy. Three key related issues are: (1) the need to maintain forces capable of dealing with two

concurrent major regional conflicts, (2) the requirement to fight expeditionary campaigns, and (3) the employment of airpower forces to achieve multiple operational objectives.

Two Concurrent Conflicts

Current U.S. national military strategy calls for the capability to deal with two concurrent major regional conflicts (that is, conflicts that may erupt sequentially, but at times must be prosecuted simultaneously). Whether or not one believes there is a high likelihood that the United States could find itself prosecuting two concurrent conflicts, sizing forces to meet more modest criteria could raise a number of risks. In the event of a major conflict in one region, such a posture could open up opportunities for an aggressor in another region. It would leave the United States vulnerable in the event a larger threat arose. It could also inhibit decisionmakers from deploying a force to a theater if they had concerns that another conflict might erupt.

A larger force structure provides flexibility and some margin for responding to the unexpected—both valuable qualities when dealing with something as inherently uncertain as military operations ten or twenty years from now. Sizing forces for two conflicts need not cost twice as much as sizing for one, since many key elements of the military infrastructure do not need to be expanded to the same level. But the two-conflict requirement does require the United States to maintain a larger force structure overall—and it heightens the importance of maintaining dominance in the airpower balance.

Expeditionary Campaigns

U.S. planning focuses on fighting expeditionary wars far from its shores. These are among the most challenging military operations to conduct. Vast amounts of cargo must be deployed thousands of miles; personnel and equipment must operate in an often unfamiliar environment on short notice. The need to deploy forces over great distances means that U.S. forces must build up over time. This will limit the size of the U.S. fighting force in the crucial early phases of an engagement—and the size of the overall U.S. theater force to only a portion of the total force.

In contrast, enemies engaged will typically be close to their home turf and can thus draw on their total force. In the initial stages of a fast-breaking conflict, a small adversary airpower force could well outnumber the initial complement of deploying U.S. forces. Adversaries could use this advantage to disrupt the exacting process of deployment, thereby reducing U.S. combat capabilities while seeking to achieve various objectives. The longer that U.S. force levels can be minimized, the greater the chances for an adversary to succeed in aggression.

The potential for attack could force U.S. forces to deploy to rear-area bases and keep carrier aviation at greater distances from the scene of combat, which in turn would reduce sortie rates and overall force effectiveness. Moreover, losses incurred in the initial phases of combat could sway U.S. public opinion and raise questions as to the wisdom of continuing the conflict.

Airpower's Multiple Operational Objectives in U.S. Military Strategy

Comparisons of the airpower balance cannot be looked at in isolation. The United States relies on its airpower to achieve multiple and often concurrent operational objectives: to gain control of the air and then exploit that medium to attack enemy surface forces and the enemy's warfighting infrastructure. *It is not sufficient for the United States to simply possess sufficient airpower to defeat enemy airpower.* That is a crucial job, but not the only one.

In contrast, if an opponent were able to dispute control of the air against U.S. forces, even for a limited period, his prospects for success would improve markedly. For example, an adversary could focus his limited airpower resources on the air defense role. The demands of U.S. national military strategy mean that U.S. airpower, on the other hand, must be capable of a much wider range of missions. These forces must not only eliminate the adversary's airpower forces rapidly and efficiently to gain control of the air, but must concurrently stop an adversary's land offensive as quickly as possible to minimize loss of terrain and conduct strikes against the enemy's warfighting infrastructure.

ASYMMETRIC STRATEGIES

Our analysis illustrates quite starkly that attempts to challenge the United States in terms of airpower will be extremely difficult. In some ways, the United States employs what might be termed an "asymmetric" strategy, one that pits U.S. strength (land-based and sea-based airpower) against most adversaries' strength (land power). But the small likelihood that potential adversaries can mount an in-kind challenge means that the United States must keep a careful eye on their prospects for developing their own "asymmetric" strategies.

The case of the Swedish air force offers a useful example for understanding what might be termed an "asymmetric" strategy. To deter a Soviet attack, the air force was envisioned to play a critical role in the defense of Sweden. The Soviet Union certainly had sufficient airpower to fight the Swedish air force "in kind." But there is strong evidence to suggest that the Soviets instead planned an "asymmetric" strategy to use special forces to kill Swedish aircrews in their homes before they could reach their aircraft.

The United States cannot assume that potential enemies will remain still. After each decisive victory, the losing side has tended to learn more than the winning side. The Gulf War was played out on a global stage and has spawned a growth industry in lessons learned. We can be confident that the various powers are studying that war to assess U.S. strengths and weaknesses.

Clearly, airpower remains a strength that the United States must strive to maintain and improve—it underpins U.S. military strategy. But asymmetric strategies could be employed to try to negate this strength. To lay out just a few possible responses, such strategies could include:

- Developing weapons of mass destruction to deter U.S. intervention;
- Developing a more lethal surface-based air defense network to deny U.S. airpower the ability to fly through enemy airspace;
- Implementing massive dispersal of strategic and military targets to deny airpower useful targets;

- Colocating key military targets with civilian structures to inhibit U.S. strikes;
- Employing special forces in attacks against key U.S. facilities, such as air bases and ports;
- Burying facilities deep underground (as North Korea has done).

Such strategies will not be easy to implement or prosecute in the face of the current and future overwhelming U.S. advantage in airpower. Only the future can tell us which strategies will be employed and whether they will be effective. It is clear that the United States must maintain its powerful air weapon in order to support its national security. And it is equally clear that the United States must also keep a watchful eye on the activities of potential foes (and develop counters where appropriate) as it enters this increasingly uncertain era.

ACKNOWLEDGMENTS

The authors would like to thank Colonel Charles Miller, Lieutenant Colonel Edward Mims, and Major Anthony Haney of XOXP, Headquarters, United States Air Force, for all their assistance in supporting this research. We would like to thank Lieutenant General Thad A. Wolfe and his staff at Air Combat Command, Major General Richard C. Bethurem and his staff at Headquarters, United States Air Force, Colonel Philip Meilinger, the dean of the School for Advanced Airpower Studies at Maxwell Air Force Base, and his able students, and Dr. Caroline Ziemke and staff from the Institute for Defense Analyses for their insightful comments on the briefing covering this analysis.

We would also like to thank Wing Commander Ken Petrie (RAF, ret.) of the International Institute for Strategic Studies for sharing insights on the methodologies involved in IISS's aircraft inventory databases. Dr. Wayne Thompson of the Office of Air Force History was also kind enough to share his data on attrition statistics and Vietnam air operations with us.

We are also most grateful to James Winnefeld and David Chu of RAND for their thoughtful and thorough reviews of the initial draft. Jack Riley of RAND did a yeoman job in the thankless task of double-checking the aircraft data. Fred Frostic, Gary Liberson, and Charles Wolf offered many keen analytic insights. Kevin Lewis was kind enough to provide some details on U.S. aircraft procurement—as well as many other useful historical insights derived from his research on trends in U.S. force structure and budgets. Benjamin Lambeth of RAND, who is currently preparing a treatise on the future of the Russian air force, was most generous in providing us with details

and insights on that service; Ken Allen (USAF, ret.) and Commander Glenn Krumel (USN) provided us with similar insights developed as a result of their research at RAND on the future of the People's Liberation Army Air Force. In support of the latter task, we would also like to thank Jon Cohen of the Institute for Defense and Disarmament Studies, whose inventory analyses proved most useful. Thomas Lucas of RAND provided us with details on the impact of accuracy upon numbers of ballistic and cruise missiles required to strike targets. And we are especially grateful to Ken Watman of RAND, who first developed the concept of "asymmetric strategies" and who is leading research in this area at the time of this writing.

We would like to thank Pam Thompson of RAND for preparing the manuscript, particularly the lengthy data tables, and providing much of the artwork employed in this report. Jerry Sollinger provided a useful smoothing of the final draft. And as always, our thanks to the talented folks in the RAND Publications Department. It is always a pleasure to work with the best.

We, of course, remain responsible for the judgments and observations contained in this report.

ABBREVIATIONS

ATACMS	Army Tactical Missile System
AWACS	Airborne Warning and Control System
C3I	Command, Control, Communications, and Intelligence
FSU	Former Soviet Union
GNP	Gross national product
GPS	Global Positioning System
IISS	International Institute for Strategic Studies
JSTARS	Joint Surveillance Reconnaissance and Targeting System
LANTIRN	Low Altitude Navigation and Targeting Infra Red by Night
RAF	Royal Air Force
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy

Chapter One

INTRODUCTION

The end of the Cold War era has introduced a new and significant set of challenges for U.S. military forces. The focus of U.S. national military strategy has shifted from the threats posed by the former Soviet Union to the threats posed by regional powers to U.S. interests. As laid out in the Department of Defense's recent "Bottom-Up Review,"[1] the vast majority of the country's defense resources will be devoted to raise, equip, and train forces to fight major theater conflicts against potential regional foes.[2]

Given the uncertainties that arise in planning for the highly dynamic security environment of the future, the United States plans to maintain a robust joint force structure to help protect its vital interests around the world. Each Service provides a unique set of attributes, and the challenge facing planners is to maintain an appropriate balance among them so that key capabilities and assets are available when needed. But within this joint context, the airpower forces provided by the three Services are receiving particular prominence. As observed by Professor Eliot Cohen, part of the reason stems from the "American way of war":

> Reliance on airpower has set the American way of war apart from all others for well over half a century. Other countries might field

[1]See Aspin (1993).

[2]Though U.S. national military strategy places other demands on U.S. forces, such as nuclear deterrence, dealing with insurgencies, and a wide range of other missions (such as humanitarian and peacekeeping operations), the resources in terms of both dollars and personnel are small compared to general purpose forces.

> doughty infantry, canny submariners or scientific artillerists comparable in skill and numbers to America's. Only the United States, however, has engaged in a single-minded and successful quest for air superiority in every conflict it has fought since World War I. Air warfare remains distinctively American—high-tech, cheap in lives and (at least in theory) quick. To America's enemies—past, current and potential—it is the distinctively American form of military intimidation.[3]

Part of the reason for the heightened emphasis on airpower in U.S. national military strategy stems from the significant role it played in the Persian Gulf War. Once the coalition had gained control of the air by disrupting and dismembering Iraq's air defense system through the employment of fighters, bombers, helicopters, ballistic missiles,[4] and cruise missiles, these same airpower forces conducted strikes against Iraq's warfighting infrastructure and surface forces deployed in and around Kuwait.

The effects of the strategic air campaign in the Gulf War remain both uncertain and controversial. But the campaign against the Iraqi army was devastating. A vast range of ground force equipment was destroyed and Iraqi forces were inhibited from maneuver, but perhaps more importantly, the morale of the Iraqi army was destroyed.[5] The implications have not been lost on other regional powers, particularly those that rely on large ground formations.[6]

In the wake of the Gulf War, the potential role of airpower in U.S. military strategy has become prominent in official documents, speeches, and congressional testimony.[7] The reasons stem in large part from the geostrategic circumstances of the post–Cold War world. U.S. force levels are being drawn down overall—and from

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[3]E.A. Cohen (1994), p. 120.

[4]The Army Tactical Missile System (ATACMS) was employed against Iraqi surface-to-air missile batteries located near the Saudi border in the initial days of the air campaign.

[5]For the most comprehensive analysis to date of the air campaign, see Keaney and Cohen (1993). For details on the campaign against the Iraqi army, see Frostic (1994).

[6]For some insights, see Lambeth (1992) and Garrity (1993).

[7]For example, in his commencement speech to the Air Force Academy on May 29, 1991, President George Bush observed: "Gulf lesson one is the value of airpower."

forward-based locations in particular. As laid out in the Bottom-Up Review, the United States is currently planning for dealing with conflicts that could erupt with minimal, if any, warning time. The primary focus is on stopping a fast-moving ground offensive launched against key U.S. allies and interests, which places a premium on forces that can deploy quickly to the scene of conflict. Highly mobile U.S. sea-based and land-based airpower are envisioned to provide the core of initial U.S. capabilities to stop such attacks. Airpower forces would be employed to gain control of the air, stop invading forces as quickly as possible, and conduct strategic strikes. Once the invasion was halted, the same forces would then be used to grind down the enemy's military capabilities while U.S. and allied ground forces continued to build up in theater. Airpower would then strike at enemy forces during the prosecution of the joint counteroffensive spearheaded by U.S. and allied ground forces.[8]

Airpower's heightened prominence in U.S. national military strategy raises two additional issues: air superiority and investment plans. First, the efficient employment of joint forces while minimizing U.S. and allied casualties requires the United States to win control of the air. The Gulf conflict—a highly successful joint campaign—provided an object lesson in the critical importance of controlling the air. Second, planned investments in airpower forces—fixed-wing aircraft, helicopters, and cruise and ballistic missiles[9]—will form a very significant portion of the nation's future procurement spending. For example, of the eight largest future procurement areas analyzed by the recent defense review, seven concerned aerospace forces.[10]

The newfound prominence of U.S. airpower, however, introduces a reason for caution. Airpower forces are not suitable for every possible type of conflict. Advanced fighters, for example, may have limited utility in jungle warfare or minesweeping operations. U.S. plan-

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[8]See Aspin (1993), pp. 15–16. For an analytic perspective, see Bowie et al. (1993). Also see Frostic and Bowie (1994), pp. 351–392.

[9]By ballistic missiles here we mean the Army Tactical Missile System. No new land-based intercontinental ballistic missiles are planned for procurement—and the sea-launched Trident missile program is winding down.

[10]The areas include theater air forces, attack and reconnaissance helicopters, ballistic missile defense, aircraft carriers, attack submarines, space launch, military satellite communications, and the V-22 Osprey tilt-rotor aircraft. See Aspin (1993), p. 34.

ners must thus be careful as force levels decline to maintain the appropriate mix of capabilities provided by the three Services.

In a broader, more philosophical sense, it is important to explore in some depth whether a U.S. military strategy based on airpower dominance is a prudent policy for the long term. If U.S. and allied airpower forces could be stalemated or severely disrupted, for example, U.S. strategy would be undermined. And the issue is not dependent just on U.S. actions, but on the decisions of other powers. Plans made by the United States with regard to military affairs are watched carefully by both friends and foes. One obvious response that other nations might make in the wake of the Gulf War would be to increase their own emphasis on airpower.

The purpose of this report is to analyze the feasibility of such an approach—to assess whether a future foe's airpower could check or stalemate U.S. airpower. The results of this analysis should help shed some light on whether other nations will seek to increase their emphasis on airpower—or seek to challenge the United States using other means.

Airpower can be doctrinally defined as the ability to use platforms operating in or passing through the air for military purposes.[11] This report employs this fairly broad definition to analyze fixed-wing aircraft, surface-to-air missiles (SAMs), helicopters, cruise missiles, and ballistic missiles.[12] Chapter Two provides some details on definitions and categories.

Chapter Three focuses on the more traditional components of the airpower balance: helicopters, SAMs, and fixed-wing aircraft. As the analysis will show, fixed-wing aircraft have historically received the primary emphasis in most of the world and form the centerpiece of U.S. airpower capabilities. Accordingly, these systems are examined more fully in Chapters Four and Five. Chapter Six examines the potential impact of less traditional forms of airpower—ballistic and cruise missiles—on the airpower balance. Chapter Seven provides some general observations and conclusions.

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[11]The USAF prefers the term "aerospace power" as opposed to airpower. See United States Air Force (1990b), p. 2-1, and Ministry of Defense (1992), p. 11.

[12]We did not examine remotely piloted vehicles in this analysis.

The Appendix provides information on our economic analysis. A companion document, MR-478/2-AF, provides details on the data employed in this report.

Chapter Two

THE DATA

For purposes of analysis, we conducted an extensive examination of the world's airpower inventories of aircraft, helicopters, surface-to-air missiles (SAMs), and ballistic and cruise missiles.[1] The true potential of a nation's airpower, of course, rests on other elements: such key issues as command, control, and surveillance capabilities and such intangibles as skilled and trained personnel. But airpower forces are equipment-intensive. Without vehicles that fly through the medium of the air, a nation does not possess airpower forces. Analysis of inventories thus can shed some useful light on a nation's potential airpower capabilities.

Examining inventories also offers other advantages. Military institutions tend to be fairly secretive about plans and intentions, but it is difficult to hide the acquisition of aircraft, helicopters, and other airpower systems. The reasons lie in the vast infrastructure required to build, purchase, and support such systems. Modern combat aircraft, for example, cost millions of dollars apiece and often form the basis for national infrastructure investment in advanced technologies. This is particularly the case in the modern era, as the number of nations capable of producing advanced fighters dwindles. Nations seeking to enhance their airpower capabilities must purchase or coproduce aircraft and other aerospace equipment, and the number of producers is limited (typically China, France, Russia, the United Kingdom, and the United States).

[1] Unclassified data on ballistic and cruise missiles are less copious than that for helicopters, SAMs, and fixed-wing aviation. Our analysis of these systems is thus more subjective than it is for the more traditional components of the airpower balance.

Given the costs and the international negotiations involved, airpower equipment choices generate a great deal of political and media attention. Accordingly, more data are available in the open literature on the various systems than on radar capabilities, transmission rates of communication networks, and other important (though difficult to measure) components of a nation's airpower capabilities.

The equipment counts used in this report include all the systems in a nation's inventory. But it is important to remember that the number of aircraft or helicopters a nation can actually bring to bear in conflict will be smaller than total inventory. For example, the United States Air Force (USAF) typically provides official inventory data for its fixed-wing aircraft in terms of Primary Authorized Aircraft or PAA. The PAA counts reflect what the USAF's inventory can yield in terms of operational force structure. To field a USAF wing of 72 PAA for 25 years actually requires a total inventory of about 130 aircraft: at any one time, some airframes are in depot maintenance, some are being used for training and flight testing, and two dozen or so are required for attrition replacement (since aircraft crash during training). Accordingly, the number of aircraft, helicopters, or SAMs a nation can actually field in combat operations will be smaller than the numbers presented in this analysis.[2]

Sorting these vast amounts of data requires making some subjective choices in categorization in order to discern patterns and trends. They are informed choices, however, based on the authors' years of research into airpower issues and supplemented by criticism and comments from a wide range of experienced military officers and civilian analysts. The ground rules for these choices are laid out in detail below. For those seeking additional details, the extensive tables in companion report MR-478/2-AF provide information on each country's holdings.

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[2]The more advanced nations may be able to mobilize a higher percentage of total inventory than other states. The United States and other Western powers attempt to extract the maximum combat potential from their substantial investment in airpower. This means maintaining fairly high crew ratios, sufficient stocks of spares to keep aircraft and helicopters in service, and adequate stores of munitions. Keeping a high proportion of airpower forces in readiness is a demanding and expensive business. It is unlikely that other powers, particularly less-developed nations, are able to maintain the same degree of readiness.

HELICOPTERS

Rotary-winged aircraft have performed an increasingly important set of military roles since the first widespread employment of helicopters took place in the Korean War. Originally used for medical evacuation, helicopters are now employed throughout the world for transport of personnel and equipment, reconnaissance, anti-submarine warfare, minesweeping, fire support, and anti-tank operations, among other missions. For our purposes here, we counted only helicopters in military service (thus excluding the large number in civilian use). Both land-based and sea-based helicopters were included in our data survey.

Helicopters are highly flexible assets, and a common platform, appropriately equipped with different subsystems, can perform a wide range of missions. Details on the specific roles assigned to each nation's rotary-winged force in this analysis are laid out in the companion report. For summary purposes, we divided the helicopters into two broad categories: utility and armed.

Utility helicopters are typically not equipped with armament (with perhaps the occasional exception of a few light defensive guns). They are employed in such roles as airlift, medical evacuation, fire control, support, survey, search and rescue, utility, light observation, minesweeping, surveillance, and special operations.

Armed helicopters are employed in land and sea combat. Some of these airframes are heavily modified variants of smaller utility helicopters. In more recent decades, more advanced models, such as the Apache AH-64, have been designed and procured specifically for battlefield operations.[3] Armed helicopters designed for land operations can be armed with guided missiles, heavy cannon, and rockets; those configured for maritime operations can be armed with a mix of guided missiles and heavy cannon (for attacks against surface vessels) and/or torpedoes and depth charges (for attacks against submarines).

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[3]These assets tend to be the most expensive and capable helicopters.

SURFACE-TO-AIR MISSILES (SAMs)

Surface-to-air missiles play an important role in assessing airpower balances (in particular, a nation's capability to defend key locations on a sustained basis). We used the number of launchers as a metric. Our primary focus was on vehicle-mounted and fixed-site SAMs operating on land; naval assets were not included.

Two general categories were employed for summary purposes:

- Short and medium range (defined as systems capable of engaging targets to a maximum range of 60 kilometers), such as the SA-2, SA-3, SA-6, SA-8, and Hawk.
- Long range (defined as systems capable of engaging targets at ranges greater than 60 kilometers), such as the SA-5, SA-10, Nike, and Patriot.

Details on individual national inventories are in the companion report. Although we strove to examine the SAM inventories of every nation in the world, our results are more likely to undercount some of these systems slightly, compared to our counts of helicopters and aircraft. SAM systems tend to be less expensive than aircraft or helicopters, and thus they receive less attention in the various data sources we employed. In addition, there is one significant gap in the unclassified data—China.

In recent decades, small man-portable anti-aircraft missiles have proliferated widely, and it is not possible to develop an inventory of these assets in an unclassified publication. To gain some perspective on the impact of this important class of systems, we examined the spread of these man-portable systems on a country-by-country basis and will provide some insights into the implications.

AIRCRAFT INVENTORIES

The primary source of aircraft inventory data employed in this analysis is *The Military Balance,* a publication of the International Institute for Strategic Studies (IISS). This London-based organization has been collecting data on the world's military forces for over three

decades.[4] Details are provided in the companion report. For an initial breakdown of this total, we broke the data into three main categories: bombers, fighters, and support aircraft.

Bombers

For purposes here, the following aircraft were included as bombers: B-1Bs, B-52s, Canberras, Il-28s, Mirage IVs, Tu-16s, Tu-22s, Tu-26s, Tu-95s, Tu-128s, and Tu-160s. The large payload and range of bombers make them well suited for a range of other missions: electronic surveillance, other forms of reconnaissance, electronic combat, and the like. Such modified aircraft are counted in the appropriate support category (see below).

Fighters

Fighters (defined here as single- and two-seat aircraft employed primarily for air superiority and/or attack missions) also offer many categorization challenges. In this analysis, only jet-propelled air vehicles were counted as fighters.[5] All fighter variants (trainers, reconnaissance, electronic warfare, etc.) were included as part of the total.

Some nations equip jet trainers with armaments to conduct ground-attack or other missions. For example, the Royal Air Force fields several squadrons of Hawk trainers armed with short-range air-to-air missiles to augment United Kingdom air defenses; other nations equipped with the Hawk use it as a ground-attack asset. But the ac-

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[4]The level of detail and quality of the data vary—in general, more recent issues offer better detail and quality. For example, data on the former Soviet Union (FSU) was dramatically enhanced following the publication of arms control data from the Conventional Forces in Europe (CFE) treaties. The accuracy of the data is also apparently directly scaled to the size of the nation in question (and its level of openness). For example, data on smaller states are easier to keep track of than data on China, which not only maintains a large defense establishment, but is highly restrictive in terms of revealing military strengths. To augment data on China, we consulted *Military Aviation News*, a now-defunct British trade publication with remarkable sources of information (apparently from industry sources).

[5]Propeller-driven attack aircraft still in service (for example, the AT-6 Texan) are included in support aircraft in the "counterinsurgency" category (see below).

tual combat capabilities of these systems are fairly limited, so we count armed jet trainers in the support aircraft category (see below).[6]

Support Aircraft

Airpower is a highly flexible force—and the wide range of support aircraft types demonstrates this flexibility. We used the following categories:

- **Counterinsurgency (COIN) aircraft:** Propeller-driven light attack aircraft, such as the AT-6. In general, these aircraft offer the same sorts of capabilities as fighter aircraft in World War II (though with enhanced armaments).
- **Armed trainers:** Jet trainers with potential combat roles.
- **Trainers:** Aircraft without attack capability.
- **Airlift aircraft:** This category covers a wide range of different types, from C-5 Galaxies in the USAF to the tiny AN-2s in service in North Korea.[7]
- **Maritime surveillance/anti-submarine warfare:** Some nations have a few business jets equipped with surveillance gear; other nations have dedicated and highly sophisticated anti-submarine warfare (ASW) aircraft equipped with homing torpedoes and sonobuoys. All are counted here.
- **Tankers:** Aerial refueling provides receiving aircraft with greater range, loiter time, and payload. The vast majority of the world's tanker fleet is found in the United States.
- **Other:** Air forces employ modified airframes for a host of other missions, such as airborne early warning radar platforms, in-

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[6]The following jets are considered armed trainers and are *not* included in the fighter category: Alpha Jet, AMX, Arao-2, AT/T-33, AT/T-37, AT/T-38, BAC-167 Strikemaster, Cheetah, CM-170 Fouga Magister, the Japanese F.1, Galeb, Hawk, IAR-93, Impala II, Jastreb, Jet Provost Mk 55, L-29, L-39, MB-326, MB-339, P-2 Kraguj, and SAAB 105.

[7]In terms of airlift assets, a number of nations, such as the FSU and China, employ military airlifters as commercial airliners; other nations, such as the United States and some European states, plan to charter commercial aircraft to augment airlift capabilities in crisis and war. The only airlift aircraft counted here are those in actual military service.

strument calibration, and so on. These aircraft are counted in this category.

BALLISTIC AND CRUISE MISSILES

Ballistic missiles and cruise missiles were first employed in combat during World War II, when the Germans conducted a terror campaign against the United Kingdom using the V-1 "buzz bomb" and the V-2 ballistic missile. The difference between these two unmanned weapons revolves primarily around the length of time they spend in engine-powered flight. Ballistic missiles use powerful engines to boost an aerodynamic vehicle to high speeds; the engine then cuts off and the missile (or its warhead) typically flies on a ballistic trajectory to the target. Cruise missiles are similar to aircraft—they typically rely on engine power for their entire flight and must be guided all the way to the target. They also usually fly at lower speeds and altitudes than ballistic missiles.

Detailed inventory data on ballistic and cruise missiles are not available in the unclassified literature, though some rough estimates of the balance can be drawn. For analytic purposes, we provide an overview of which nations field (or are developing) ballistic and cruise missiles, the advantages and disadvantages of these systems compared to fixed-wing aviation, and the outlook for these systems in the future.

Chapter Three

INITIAL STEPS IN ASSESSING THE AIRPOWER BALANCE

In 1991—a year that witnessed the Persian Gulf War, the demise of the Soviet Union, and, for all intents and purposes, the end of the Cold War—the world's powers had over 36,000 helicopters, about 33,000 SAM launchers, and 66,000 aircraft in service.[1]

Figure 1 provides an overview of the overall numbers—as well as an initial breakout of the various systems by the categories employed in this analysis. A few points can be drawn from this planetary perspective:

- There are more aircraft than helicopters or SAM launchers. Moreover, aircraft, particularly bombers and fighters, tend to be more expensive in terms of unit cost than either SAMs or helicopters. This indicates that the world's powers have historically placed a greater emphasis on fixed-wing aircraft than on either rotary-winged craft or SAMs.
- Some important concentrations of specific systems were found at the close of the Cold War. For example, about one-third of the world's military helicopters belonged to the United States; about one-half of the SAMs belonged to the former Soviet Union (FSU). Details on these concentrations will be analyzed further below.

[1]As noted in Chapter Two, developing an accurate inventory of the world's ballistic and cruise missiles is not possible in an unclassified publication. Issues relating to these systems are analyzed in Chapter Six.

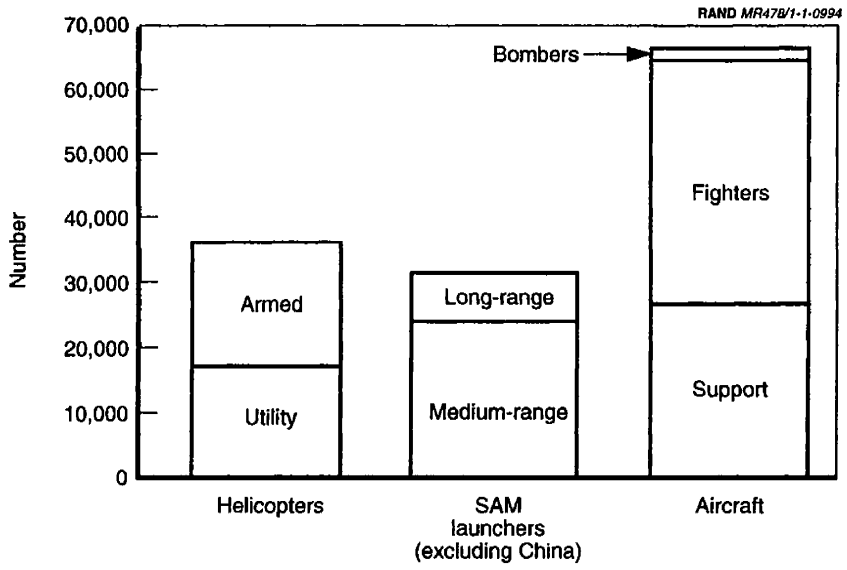

Figure 1—Global Airpower Inventories, 1991

DEFINING REGIONS

The next step in the analysis was to see in which general areas of the world these systems are located. For analytic purposes, we first broke out the three major powers (the United States, the FSU, and China) and then aggregated separate countries in the following regions:

- Latin America
- North Africa
- Sub-Saharan Africa
- The Middle East/Southwest Asia
- South Asia (which includes the Indian subcontinent and Southeast Asia)
- The nations of the Pacific Rim

- Eastern Europe (which contains those states from the former Warsaw Pact)
- Western Europe (including Western neutrals such as Switzerland and Sweden, as well as NATO member Canada).

These broad regions, which are laid out in Figure 2, provide some initial insights into the airpower balance. For an additional perspective, we provide country-by-country inventories in the analysis laid out below. We will now consider each major set of systems in turn: helicopters, SAMs, and fixed-wing aircraft.

ROTARY-WINGED AVIATION

When examining the distribution of rotary-winged aviation by region (as shown in Figure 3) and by country (as shown in Figure 4), the dominance of the nations on the "front lines" of the Cold War is readily apparent. The United States alone possessed almost one-third of the world's total. Western Europe's inventories comprised about 17 percent, and the FSU a slightly smaller percentage.

As the widespread proliferation of military helicopters implies, rotary-winged aviation has proved to be a highly flexible instrument capable of conducting a wide—and increasing—range of important missions. Viewed in the context of this analysis, however, helicopters did not prove essential to assessing potential airpower challenges to the United States. Simply put, helicopters are poorly suited for one crucial, but vital, mission: control of the air.[2] Helicopters have only a limited capability to shoot down high-performance fighters in aerial engagements; fighters, on the other hand, can pose a serious threat to airborne helicopters. Helicopters can also be typically be outranged by fighters, making bases that support rotary-winged assets vulnerable to attack.

Operational and tactical measures can reduce helicopter vulnerability to fixed-wing aviation. Mobile maintenance, rearming, and re-

[2]Gaining control of the air requires prosecution of a wide range of activities, such as offensive fighter sweeps with air superiority aircraft, attacks against air bases with strike aircraft, and suppression of enemy air surface-based defenses. Helicopters have only a limited capability to contribute to this mission.

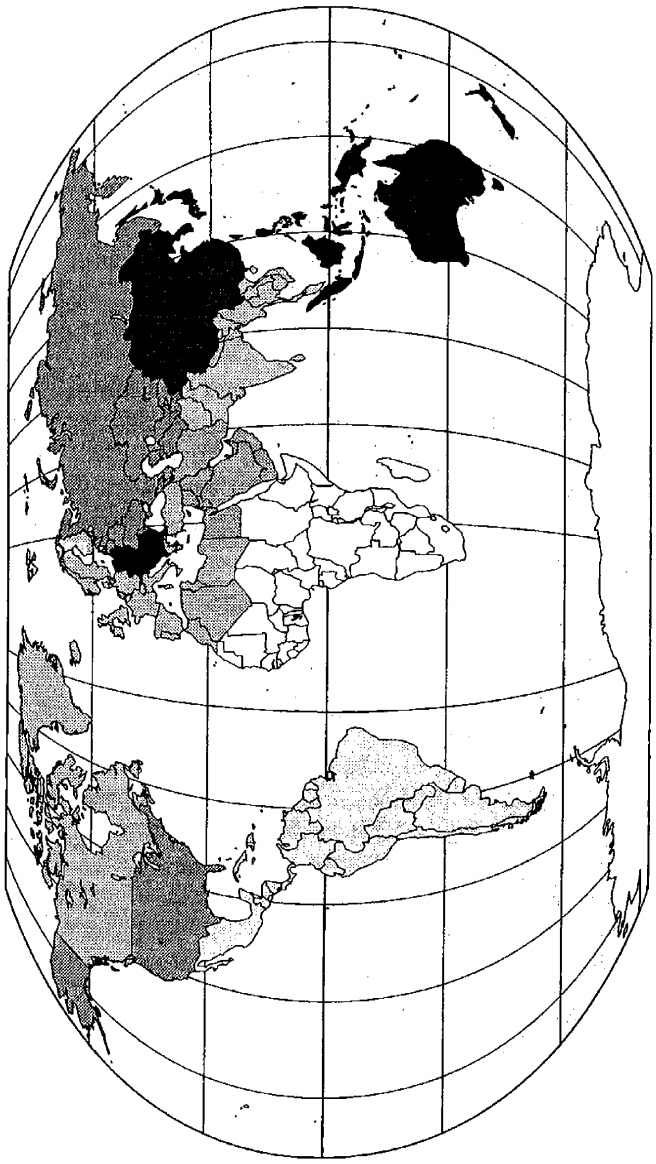

Figure 2—Defining Regions

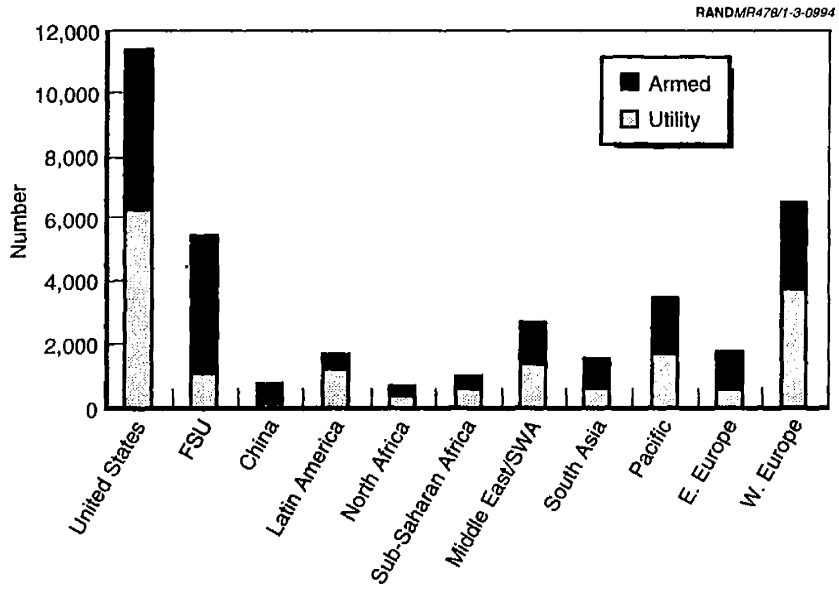

Figure 3—Helicopter Distribution, 1991

fueling facilities, for example, can make it more difficult for fixed-wing combat aircraft to find and attack helicopter bases. Helicopters in flight can be difficult to detect and engage by fighters, since their rotor blades and engine exhaust signatures can blend into the background clutter when flying low. Moreover, differences in speed, altitude, and agility can make a helicopter a difficult target for an attacking fighter, particularly in the presence of ground-based air defenses. Still, the *relative* vulnerability of helicopters to fighters means that no prudent commander would wish to conduct helicopter operations in the face of an adversary fielding capable fighter forces.

The potential roles of rotary-winged aviation in combat continue to grow. Indeed, helicopters can perform some missions much more effectively than fixed-wing aviation, such as certain types of fire support, search and rescue, and insertions of special operations forces, among others. But helicopters cannot effectively dispute control of the air. Accordingly, if adversaries were to spend resources to de-

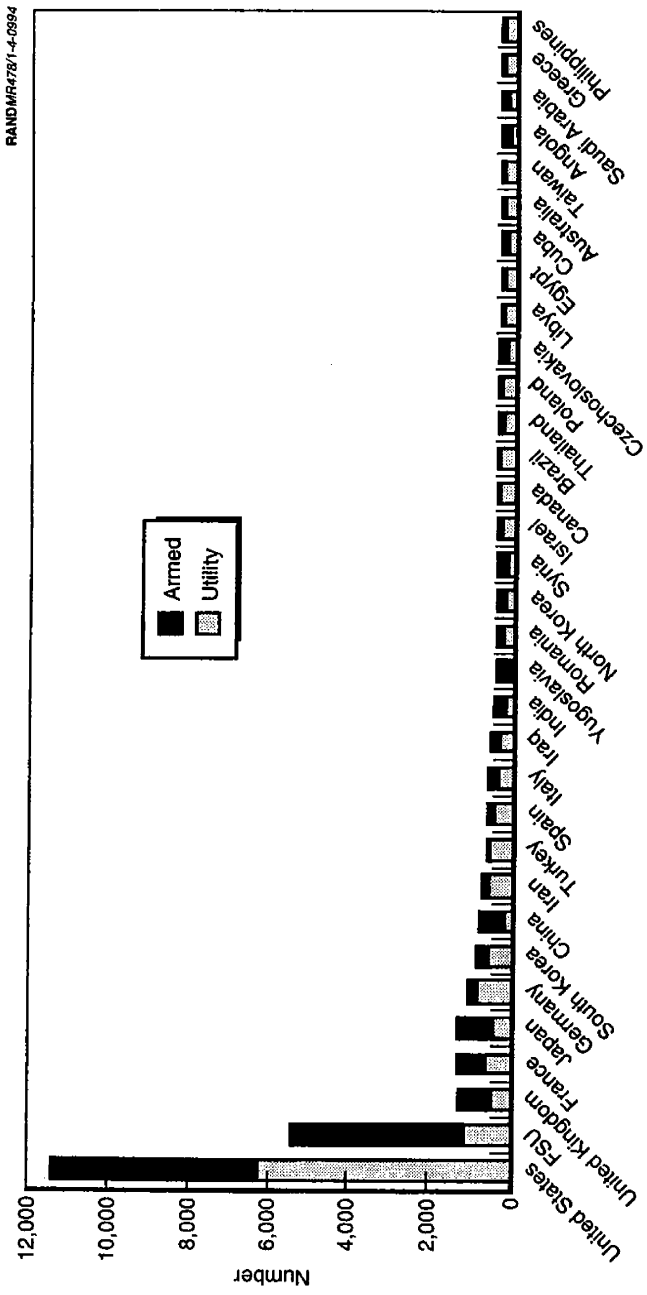

Figure 4—Helicopter Inventories by Country, 1991: The Top 30

velop more capable helicopter forces, such a policy's ability to shift the balance of airpower against the United States is highly questionable. We therefore must focus our analysis on the other components of the airpower balance.

SURFACE-TO-AIR MISSILES (SAMs)

In contrast to helicopters, SAMs *can* dispute control of the air. Figure 5 gives an overview of the regional distribution of the world's SAMs at the close of the Cold War; Figure 6 is an overview of the top 30 holders of SAM systems next to the FSU.

One of the most striking features revealed by these figures is the vast number of these systems, particularly long-range systems, maintained by the FSU. The Soviet Union owned approximately 50 percent of the world's total inventory of SAMs and 70 percent of the world's total inventory of long-range SAMs. The fragmentation of that nation, however, into the Commonwealth of Independent States (CIS) in turn indicates that these systems will now be found distributed in varying densities among the newly formed republics. At

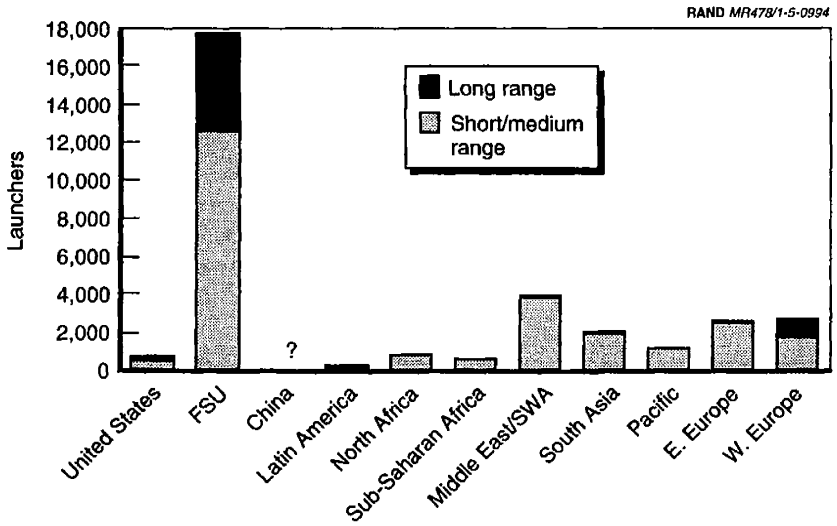

Figure 5—SAM Inventories, 1991

the close of the Cold War, other considerable concentrations of SAMs were found in Western and Eastern Europe and the Middle East/SWA; countries from these regions also show up fairly prominently in Figure 6, which details individual national inventories.

Have SAMs received greater emphasis than fixed-wing aircraft? To gain a perspective, Figure 7 depicts the ratio of SAM launchers to fighters in the various regions to illustrate the relative degree of investment in these systems compared to fixed-wing aviation. As can be seen, in most of the world the ratios rarely exceed one to one—the key exceptions being the Middle East/SWA, Eastern Europe, and the FSU. The United States in particular has a very low ratio.[3] Because individual fighter aircraft tend to cost more than SAMs, the data illustrate that to date, fixed-wing systems have enjoyed priority in terms of investment.

The reasons for such disparities in investment priorities are complex. Fighter aircraft are obviously more flexible than SAMs, particularly multirole aircraft capable of conducting air superiority and surface attack missions. In addition, except for some very-long-range systems such as the SA-5, SAMs cannot dispute control of the air in enemy airspace.

SAMs are also poorly suited to maintaining air sovereignty (typically an important mission for nations), owing to their limited coverage area and their inability to visually identify targets before engaging. And their poor area-coverage capabilities reduce their cost-effectiveness. Although individual SAM systems tend to be less expensive, large numbers must be procured to defend larger areas.

Figure 8 provides a conceptual overview of the area coverage provided by a fairly inexpensive fighter such as the F-16 compared to

[3]This reflects the traditional emphasis in the U.S. military on fixed-wing aviation for air superiority. This emphasis is likely to continue for two main reasons. First, the United States plans to conduct expeditionary campaigns, and far less material must be airlifted to support air superiority aircraft to defend a given volume of airspace than to support SAM batteries. Second, and perhaps most important, institutional and doctrinal pressures place a much greater emphasis on fixed-wing aircraft than on SAMs in U.S. military policy.

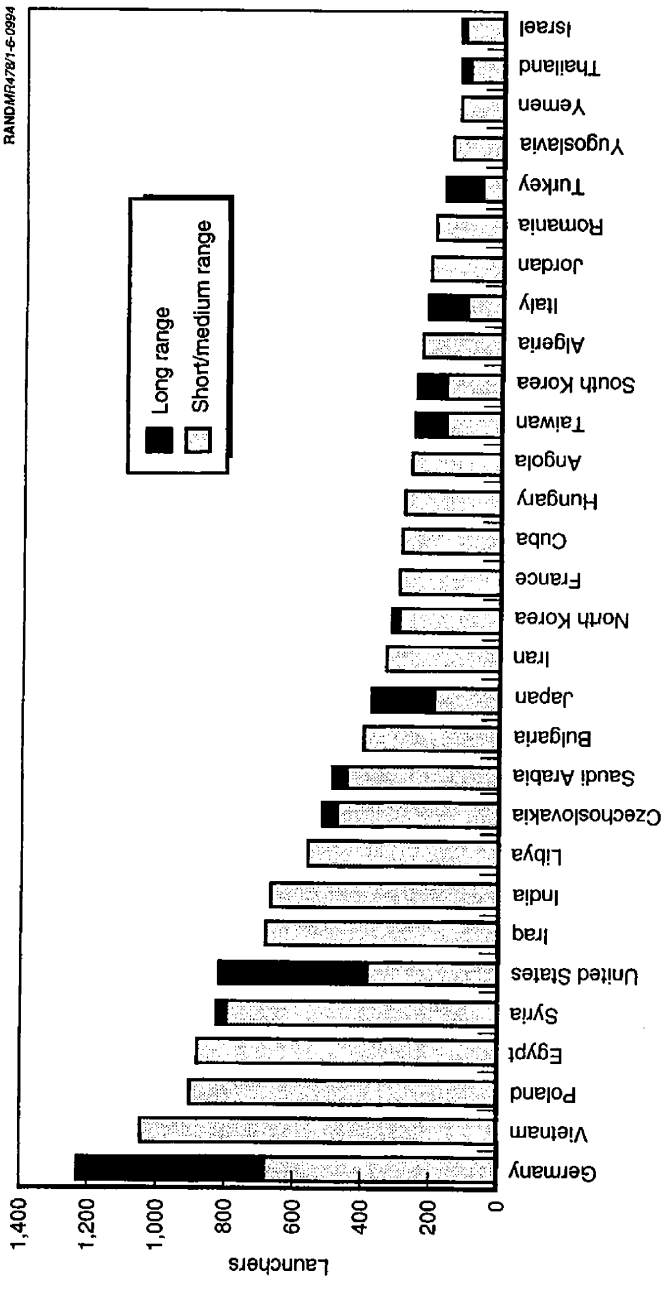

Figure 6—Surface-to-Air Missile Inventories by Country, 1991: The Top 30 After the Former Soviet Union

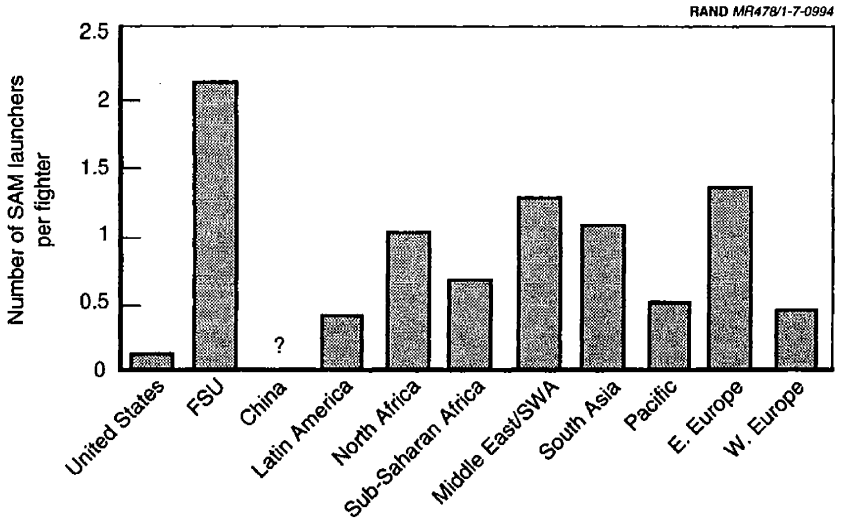

Figure 7—SAM-to-Fighter Ratios

both medium- and long-range SAMs.[4] An F-16 can cover over 177 times the area of a medium-range SAM and 64 times the area of a long-range SAM. These relative comparisons are, of course, simplistic. A SAM battery, for example, can offer sustained coverage of a particular area, whereas a fighter can offer coverage for only a limited time. Nonetheless, fighters have important advantages in terms of area coverage capabilities.

Recent years, however, have seen a widespread—and apparently accelerating—proliferation of man-portable SAMs. These systems, typically equipped with infrared guidance mechanisms, are not only being procured from advanced nations; a growing number of nations

[4]The area the systems can cover is computed assuming that the F-16's combat radius is 800 km, the medium-range SAM's is 60 km, and the long-range SAM's is 100 km. At 800 km, an F-16 can loiter on a CAP (combat air patrol) station for approximately 45 minutes (which if turned into radius would add another 270 km to the F-16's combat radius). For additional details on F-16 interceptor ranges, see Stanley and Liberson (1993), p. 61. Computing average combat radii of fighters and average engagement ranges of SAMs is a highly complex business—the numbers employed here are for comparative purposes only.

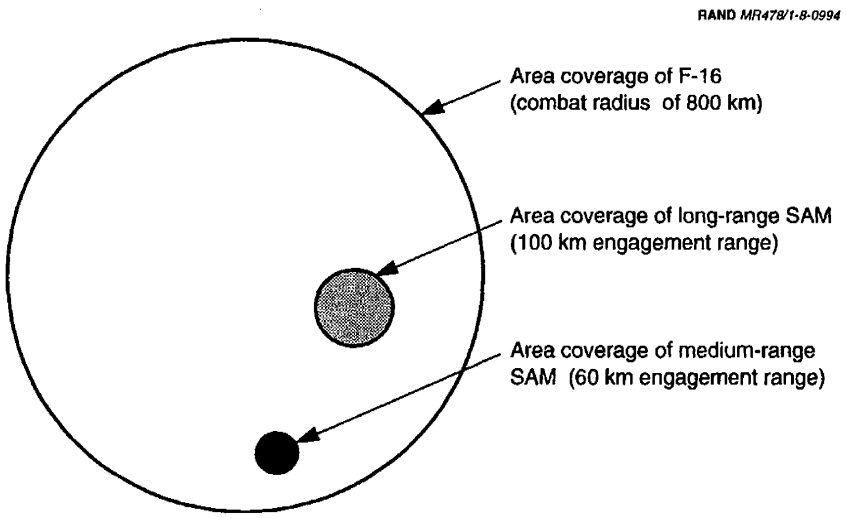

Figure 8—SAM Versus Fighter Area Coverage Comparison

are producing their own (which in turn increases the proliferation potential).[5] Compared to fighters and radar-guided SAMs, man-portable SAMs are relatively inexpensive. And they have proved quite lethal, as the Soviets learned in Afghanistan when they were confronted with U.S.-made Stinger missiles in the hands of guerrilla forces.

The primary defenses that fixed-wing aircraft employ when operating in the presence of man-portable SAMs include such countermeasures as flares and flying outside the range of these weapons (typically at altitudes above 15,000 feet). The effectiveness of flares, however, is likely to decrease dramatically in the future due to the increasing electronic "smarts" of guidance systems (in particular, the development of new imaging infrared guidance packages). Nonetheless, flying at altitude, as was done in the Gulf War, should remain effective for some time, since physical limitations continue to inhibit the range of man-portable SAMs. A SAM that can reach higher alti-

[5]Taiwan, the United States, Russia, the United Kingdom, Sweden, China, France, and Pakistan all produce man-portable SAMs indigenously.

tudes must be made physically larger, which in turn increases cost and requires that the system be mounted on a vehicle or fixed-site launcher. And radar guidance would then typically be needed to provide some vectoring for the missile, since acquiring and then locking the missile's guidance system onto an aircraft flying at such altitudes is very difficult to do using only optical sights.

The spread of man-portable SAMs, in combination with the already widespread proliferation of anti-aircraft guns, could limit—and, in fact, may already have limited—the capability to operate fixed-wing aircraft at low altitudes over certain areas. Attempting to suppress thousands of individually aimed missiles and gun defenses from the air is simply not a feasible operation. This indicates that in order to operate with acceptable attrition levels over heavily defended areas, fixed-wing aviation will have to fly at medium and high altitudes.

Since U.S. military strategy relies upon fixed-wing airpower to penetrate enemy airspace for a variety of operational objectives, these developments have important implications. Before the Gulf War, the United States Air Force, Navy, and Marine Corps emphasized equipping aircraft with systems that would allow aircrews to deliver inexpensive general-purpose bombs with great accuracy from low altitudes. Only about one-sixth of the force in the Gulf War, for example, had the capability to deliver laser-guided weapons (even though the technology dated back to the mid-1960s).[6] For a variety of reasons (ballistics, changing wind patterns, etc.), these systems cannot deliver general-purpose ordnance with high accuracy (e.g., less than 10 meters) from medium and high altitudes. The desire to minimize loss rates in the Gulf War led to the decision to fly outside the range of gun and man-portable SAM defenses; this decision reduced casualties, but it also had the effect of rendering large portions of the airpower forces in theater (notably the F-16s and F-18s) very inaccurate.[7] The tactics required to operate with minimal losses in the face of man-portable SAMs and anti-aircraft guns will require greater

[6]The USAF provided 42 F-117s, 66 F-111s, and a dozen or so F-15Es when the latter were equipped with LANTIRN pods. The USN/MC provided 115 A-6 aircraft with similar capabilities. Over 1,200 U.S. fighter aircraft were deployed to the theater.

[7]See Keaney and Cohen (1993), pp. III-6–III-7.

emphasis in the future on guided ordnance and target-acquisition systems that can locate targets from higher altitudes.

If low-altitude operations have been compromised, U.S. military strategy demands that careful attention be paid to ensuring the capability to operate at medium and high altitudes for the long term. The Cold War offers a useful example. In preparing for combat in Europe, NATO relied heavily on airpower to help offset the decided Warsaw Pact advantage in ground forces. But the vast investment the Soviets and their allies had made in radar-guided SAM defenses (not to mention fixed-wing fighters) led NATO air forces, particularly those maintained by the Europeans, to place a heavy emphasis on low-level penetration tactics. Planners and operators believed the latter would enable aircraft to survive by flying under radar horizons, exploiting terrain masking, and minimizing exposure to hostile fire.[8] To support this approach, low-level flying figured prominently in the training curriculums of most NATO air forces, and some aircraft, such as the U.S. F-111 and the European Tornado, were designed specifically to operate at low altitudes.

The Warsaw Pact, however, had also made a heavy investment in man-portable SAMs and gun defenses. So in the wake of operational experience in Vietnam (where most losses were due to guns) and the Gulf War (where most losses were due to SAMs), it appears that NATO airpower operations in the event of a war in Europe could have suffered very heavy losses indeed. And had attrition rates been high enough, they could have forced the NATO air commanders to consider switching to medium- and high-altitude penetration tactics in the midst of combat or shifting air strategies substantially. This could obviously have been a disastrous development for NATO.

Could nations with sufficient motivation deny U.S. forces the use of the medium- and high-altitude sanctuary? That, after all, was what it

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[8]The Royal Air Force in particular was doctrinally wedded to low-level penetration tactics and exerted a great deal of influence over the thinking of other NATO air forces (many of which had flown as RAF squadrons in World War II). An important reason for the RAF's doctrine was its poor position in terms of modernization when NATO shifted strategy to flexible response. In the mid-1960s, the British government canceled all of the RAF's primary aircraft programs, leaving it to deal with Warsaw Pact forces while equipped with a fairly obsolescent set of aircraft. For additional insights, see Stein (1987).

appeared the Warsaw Pact was developing. The fairly modest number of SAMs in individual national inventories (see Figure 6) indicates that to date, outside the FSU, most powers have not emphasized SAM systems. To procure sufficient numbers of SAMs capable of reaching into the higher altitudes—which would enable greater areas to be defended and/or increase the density of defenses around critical targets—could prove costly. In essence, the greater the capability, the costlier the systems, and the less their cost advantage over fixed-wing aircraft. But it is possible that nations could attempt such an operational strategy, and one lower-cost approach would be to acquire these systems from the states of the FSU.

Whether air defenses that place a heavy emphasis on SAMs could successfully deny airspace to fixed-wing operations raises many complex issues. Counters employed by aircraft include maneuver, deception, countermeasures (such as jamming, chaff, and flares), lethal suppression (which involves direct strikes against SAM batteries and radars), and stealth. The defenses in turn will react, and the action-reaction cycle will continue to the next phase.[9]

Traditional means of dealing with SAM air defense networks involve the use of jamming aircraft (which can help blind defenses) and lethal defense suppression aircraft (such as the F-4G Wild Weasel, which can destroy radars and SAM sites). But conducting such conventional rollback campaigns takes time and can turn into a costly attrition battle (as was seen in the deadly duels during the Vietnam War between U.S. fighters and North Vietnamese SAMs and during the 1973 war in the Middle East between Israeli fighters and Arab SAMs).

SAM-based air defenses are critically dependent upon early warning radars and centralized command and control. Radar returns from penetrating aircraft are plotted and then exploited by air defense commanders to cue SAMs and permit the most efficient and effective use of these systems.[10] Accordingly, low-observable stealth aircraft offer a tremendous advance in dealing with surface-based defenses. Stealth aircraft can deny warning and situational awareness to en-

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[9]For a most useful historical overview of this process, see Werrell (1988).

[10]See United States Air Force (1990a).

emy air defenses. This allows strikes at the heart of a SAM-based defense system and, as was seen in Iraq, the ability to shatter centralized control and permit the defeat of the remaining network in detail. Developing counters to stealth aircraft, moreover, will be extremely difficult.[11]

Regardless, U.S. reliance on fixed-wing aircraft to support its military strategy means that planners must be careful to ensure that the United States can penetrate adversary airspace with reasonable levels of attrition. This will require continued investment in such traditional means as jamming assets and lethal defense suppression systems, stealth aircraft, and the development of new concepts altogether. Without such attention, the deployment of dense SAM defenses has the potential to undermine U.S. national military strategy.

FIXED-WING AIRCRAFT

Figure 9 shows what the various regions maintained in terms of fixed-wing inventory at the close of the Cold War; Figure 10 provides an overview of the top 33 largest airpower forces. The United States, the FSU, Western Europe, and China maintained the largest numbers of aircraft—and their combat forces dwarfed those of the remaining nations.

Only the largest states—China, the FSU, and the United States—maintained any sizable inventories of bombers. This is not unexpected given the great costs of procuring and maintaining these weapon systems. Overall, though, fighters represented the dominant combat capabilities of the world's foremost airpowers. As shown in Figure 9, roughly one-third of the U.S. fighter inventory was provided by the Navy and Marines, the remainder by the Air Force. In the rest of the world, naval aviation assets typically comprised only a small fraction of the airpower forces.

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[11]The United States has maintained an active "Red Team" program to try to develop means to counter stealth for several decades. To date, these efforts have not developed a successful set of counters. See United States Air Force (1990a). But the number of stealth aircraft maintained by the United States—the only operator of these systems—will remain very small for many years. Accordingly, some measures might include the development of mobile or extremely hardened command and control facilities, deception, and the proliferation of potential targets.

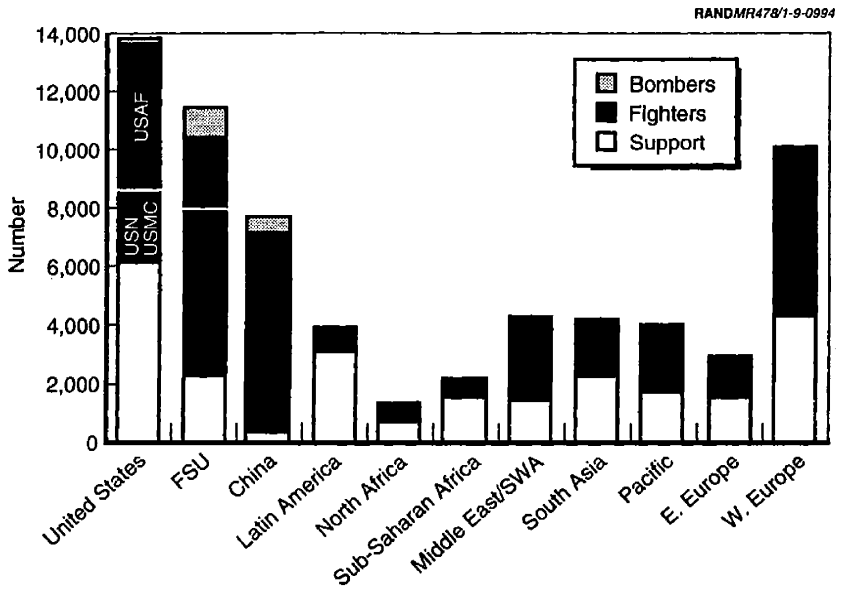

Figure 9—Regional Distribution of Fixed-Wing Aircraft, 1991

All regions maintained sizable inventories of support aircraft. But, as shown in Figure 10, few nations maintain higher support-to-combat ratios than the United States. And closer examination of the data reveals a substantial disparity in capabilities. U.S. support aircraft tend to be larger, longer-ranged, and more capable than those of other nations. Where the United States maintains intercontinental jet transports like the C-141B and C-5A/B, medium powers will field a handful of medium-range transports (such as the C-130) and some business jets for transport and internal communications, and small states may maintain only a few business jets. Similarly, the U.S. Navy maintains a large fleet of highly sophisticated anti-submarine warfare aircraft (the P-3 Orion). Medium-sized powers (such as the United Kingdom and France) maintain smaller fleets of assets with similar capabilities, while smaller powers either do not own any such assets or tend to be equipped with converted aircraft carrying less sophisticated sensors and weapons. In essence, the capabilities—and costs—of U.S. support aircraft are much greater than those typically maintained by other powers, and these assets provide U.S. combat forces with greater range, flexibility, and effectiveness.

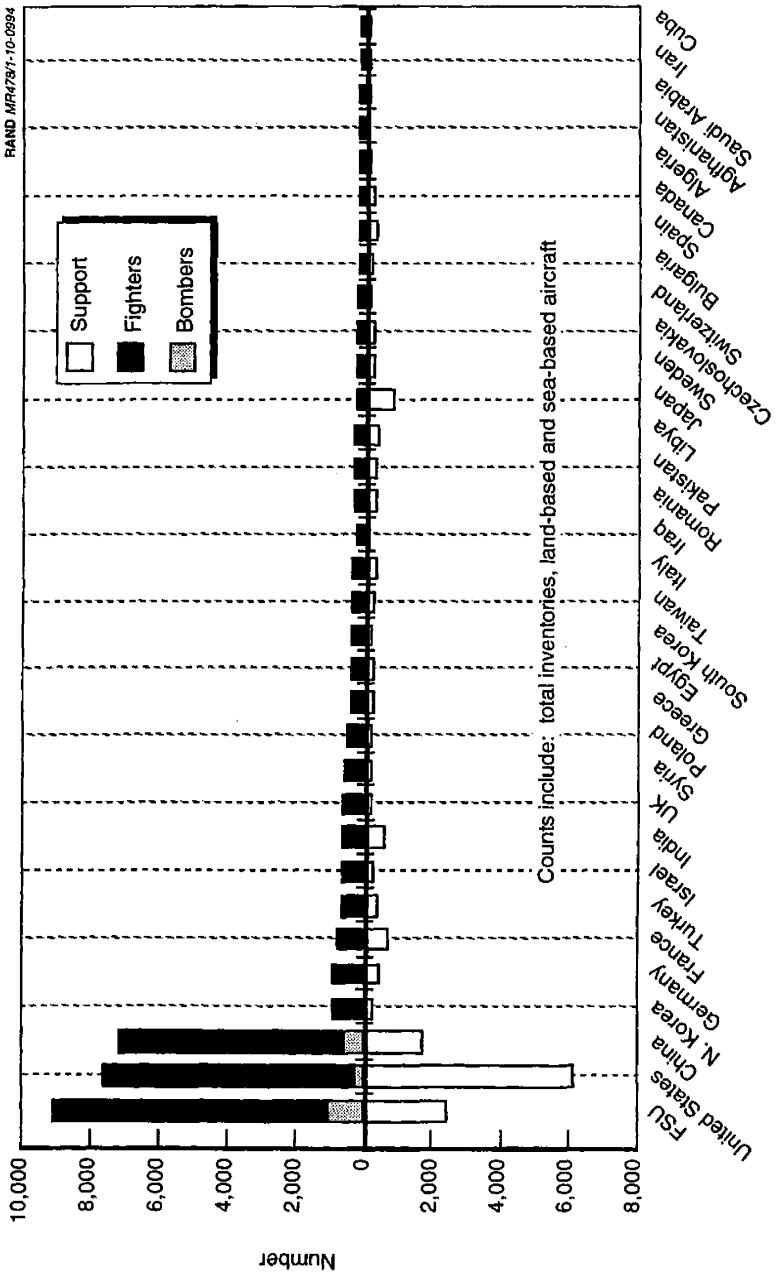

Figure 10—Distribution of Aircraft by Nation (Top 33 Powers), 1991

Chapter Four

THE GENESIS AND DIMENSIONS OF THE GLOBAL FIGHTER BALANCE

Within the fixed-wing category, fighters form the dominant component of airpower combat capabilities.[1] Accordingly, we will now focus on the global fighter balance.

Figure 11 provides an overview of trends in the number of fighters maintained by the world's air forces in three separate years: 1971, 1981, and 1991. Over this twenty-year span, what is remarkable is the fairly steady state in terms of overall numbers. After all, the costs of fighter aircraft have increased dramatically in these years, and intuition would lead one to believe that the numbers would decline. In point of fact, numbers have stayed fairly steady and perhaps even increased in the 1980s (although changes in counting rules and data anomalies in the source data may be partly responsible for this finding).

The trend illustrated by these data is also consistent with two other data sources: analysis of the USAF inventory since 1950, drawn from the *Air Force Statistical Digest,* and data gathered by Project AIR FORCE on the allied air forces of NATO's Central Region. As can be seen in Figure 12, which displays the USAF inventory over time, the numbers of fighter aircraft maintained in inventory stayed remarkably stable from the mid-1960s (which coincided with the introduction of the flexible response doctrine). In the 1980s, the USAF inven-

[1]Although bomber aircraft offer important combat capabilities, particularly in the United States with the introduction of new precision munitions, they are small in number compared to fighters. For an assessment of their potential impact on theater combat operations, see Bowie et al. (1993).

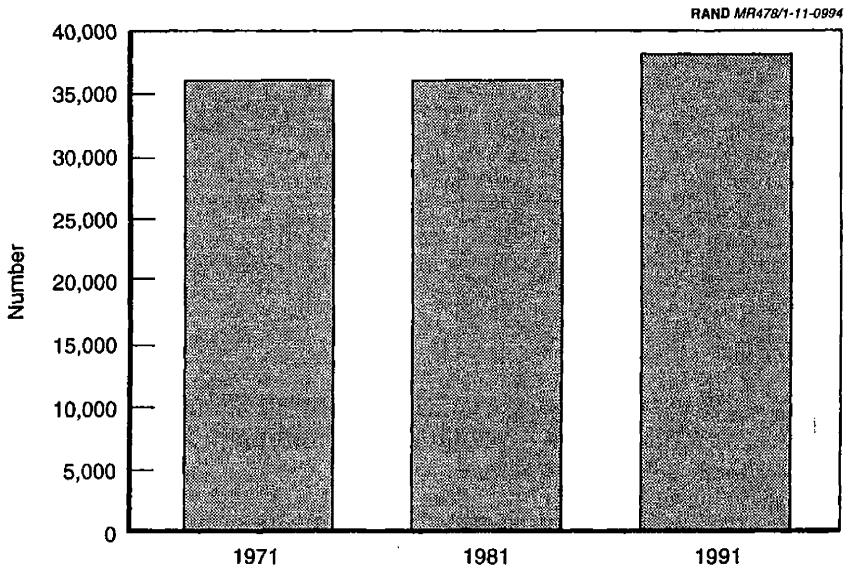

Figure 11—Trends in Global Fighter Inventories

tory expanded slightly. As the graph shows, the increase in costs of individual aircraft was offset by increases in useful service lives. Whereas such aircraft as F-80s and F-86s had service lives measured in years (a product of airframe fatigue as well as the advancing pace of technology), the Century-series fighters (F-100, F-101, F-102, F-104, F-105, and F-106) had service lives measured in decades, as have subsequent aircraft (F-4, F-111, F-14, F-15, and F-16). Fewer numbers were procured, but inventories were maintained. Aircraft, of course, did wear out and have to be replaced, but at a slower rate compared to older systems.

Figure 13 gives an overview of the inventories of air forces in NATO's Central Region (measured in numbers of squadrons).[2] Again we see the same sort of pattern. Inventories declined to roughly a steady state in the mid-1960s and expanded slightly in the 1980s. Fighters procured in the wake of the Korean War rapidly left service, while

[2]See Bowie, Lorell, and Lund (1990). For an update, see Lorell (1992).

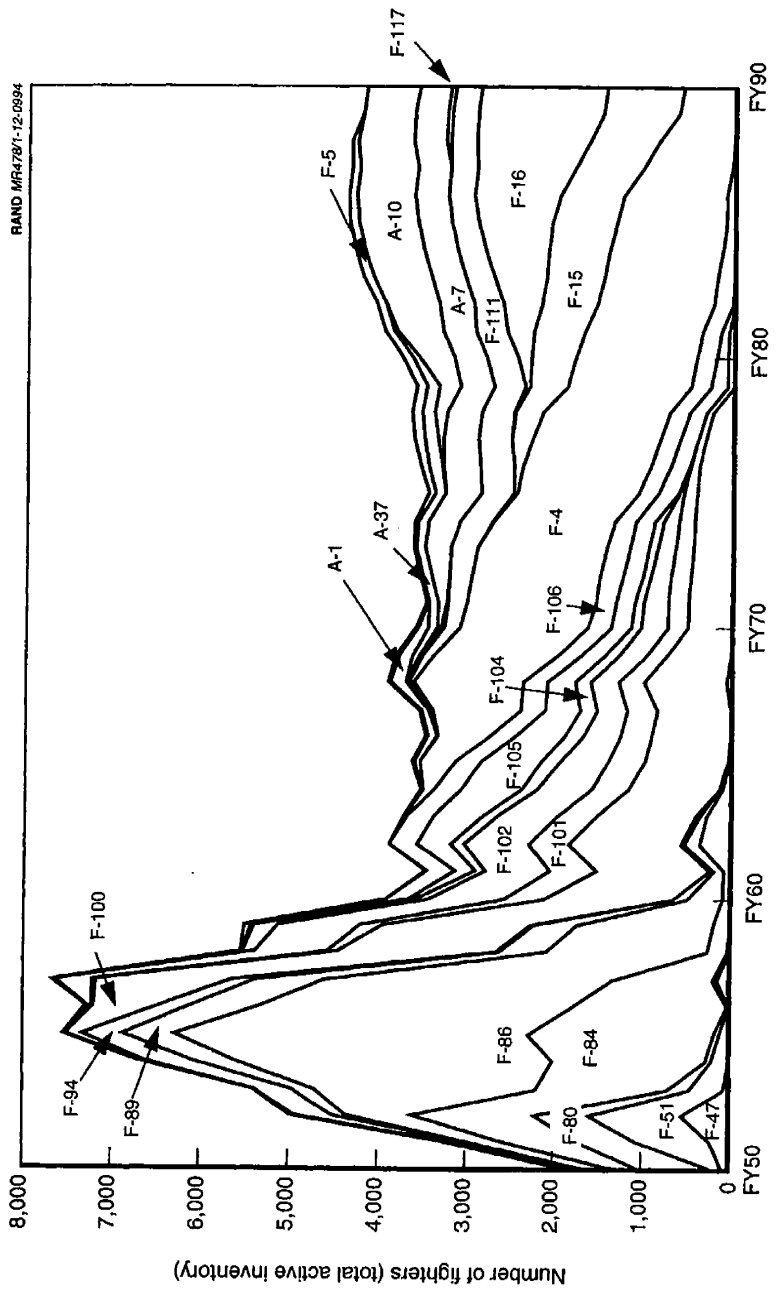

Figure 12—The USAF Inventory, 1950–1990

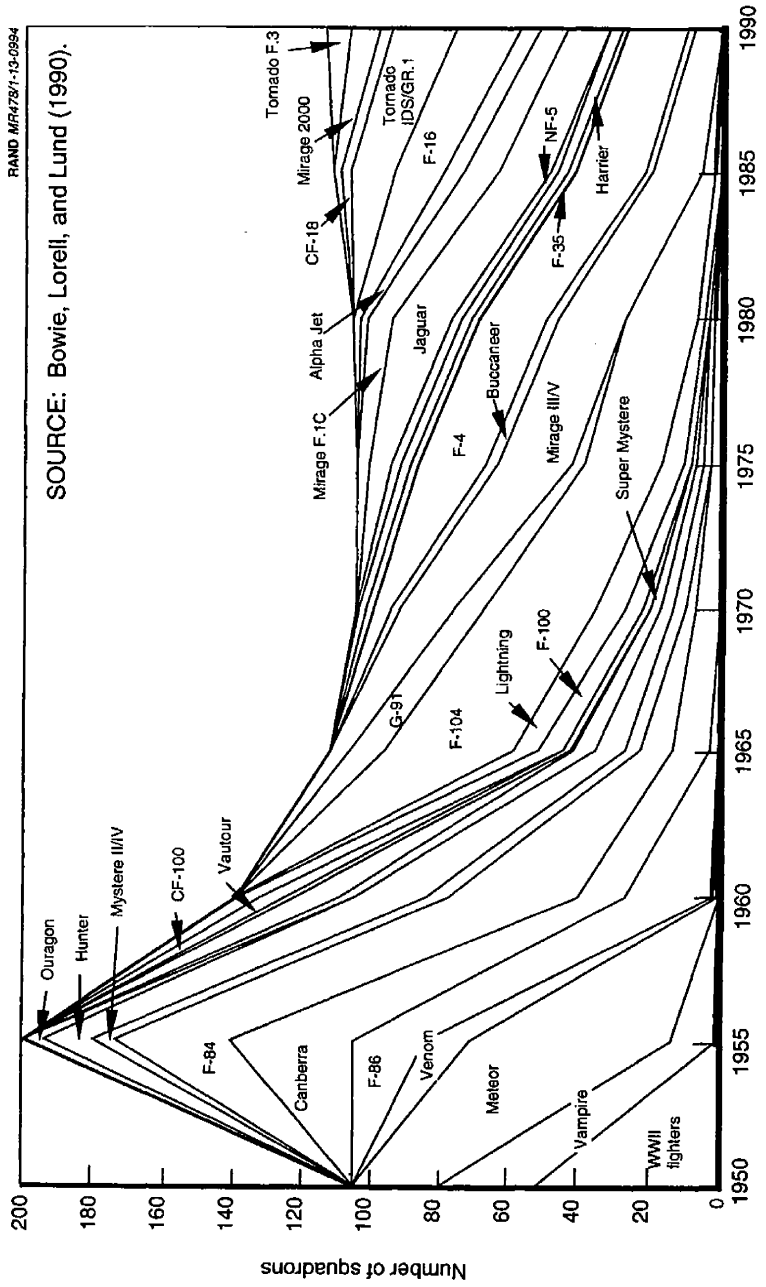

Figure 13—Inventories of NATO Central Region Air Forces, 1950–1990

newer generations lasted much longer in service (thus allowing the air forces in question to retain numbers in the face of increased platform costs).

Though the data are not available in such levels of detail from *The Military Balance* (for example, numbers on China and the Soviet Union are quite rough for 1971), it appears from these three separate data sources that the same pattern typically describes the evolution of fighter forces in the rest of the developed world. The patterns in the developing world were somewhat different—as these nations first formed in the wake of World War II, they began to develop their militaries. Accordingly, their airpower forces gradually built up during the 1950s and 1960s, after which it appears they too reached a fairly steady state.

In general terms, it appears that the airpower forces of the world reached a "desired" level in the mid-to-late 1960s and have maintained fairly consistent levels until now. There has been remarkable stability in terms of the fighter inventories since 1971, and probably since the mid-1960s. The prospects that airpower forces will maintain these levels will be explored in subsequent sections.

CONSIDERING CAPABILITIES

The preceding has simply provided raw numbers. But airpower combat capabilities are particularly sensitive to technological sophistication. An air force may possess thousands of old fighters but be simply unable to deal with another power possessing hundreds of modern fighters.

Assessing the relative capabilities of fighters is a highly subjective process. For example, the F-111 is a fairly old fighter with design origins dating back to the early 1960s. But it remains a critical aircraft in the USAF and is planned to be in service for another decade or so. Variants of aircraft can possess highly different capabilities. For example, the initial production versions of the F-16A were primarily suited to close-in, day-only air combat and day-only ground attack. Later variants of the F-16C equipped with advanced avionics and modern weapons can conduct night/adverse weather air-to-air combat and ground-attack missions. The following categorization is

based primarily upon aircraft design age—that is, when the aircraft was initially developed.

There were almost 50 different kinds of fighters in service in the world at the close of the Cold War. The analysis employs three major categories:

- **Front-line:** These aircraft represented about 25 percent of the world's total inventory. They are regarded as the cutting edge of modern fighter forces and were designed primarily in the 1970s and 1980s. The aircraft included in this category are: F-14 Tomcat, F-15 Eagle, F-16 Fighting Falcon, F-18 Hornet, F-117, Mirage 2000, Tornado, Su-24 Fencer, Su-27 Flanker, MiG-29 Fulcrum, and MiG-31.
- **Useful:** These aircraft represented about 25 percent of the world's total inventory. They offer useful combat capabilities, but in general their design age dates back to the late 1950s and 1960s. The aircraft included in this category are: A-7 Corsair II, Dassault Super Entendard, F-4 Phantom II, F-111 Aardvark, J/A-37 Viggen, Jaguar, Mirage F.1, MiG-23/27, and MiG-25. This category also includes a number of more modern but specialized aircraft of limited capability, such as the A-10 Thunderbolt II, Harrier, J-8, Su-25, and Yak-38. These latter aircraft comprise only a small proportion of the world's fleet of aircraft, so including these assets in the "useful" category as opposed to "front-line" does not appear to skew the findings of the analysis to any considerable degree.
- **Old:** These aircraft represented about 50 percent of the world's total inventory. They date back primarily to the 1940s and 1950s in terms of design age. The aircraft included in this category are: A-4 Skyhawk, Buccaneer, F-86 Sabre, F-5 Tiger II, F-8 Crusader, F-104 Starfighter, Hunter, G-91, J/A-35 Draken, Q-5, MiG-15 (J-2), MiG-17 (J-5), MiG-19 (J-6), MiG-21 (J-7), Mirage III/V and related Kfir variants, Ouragon, Super Mystere B2, Su-7, Su-15, and Su-17/20/22.[3]

[3]The Chinese variants of Soviet aircraft—the J-2, J-5, J-6, and J-7—are counted as MiGs.

Figure 14 shows the top 20 fighters at the end of the Cold War in terms of numbers and capability. The 20 most numerous accounted for around 83 percent of the planetary total, the 26 other types for the remainder. The most numerous fighter in service at the close of the Cold War was the MiG-21 (and its Chinese-produced variant, the J-7) followed by the MiG-19 (J-6) and MiG-23/27. The F-16 was the most numerous front-line fighter in the world.

Figure 15 then distributes these aircraft across the various regions of the world to illustrate some interesting patterns at the close of the Cold War:

- The vast majority of the U.S. inventory consisted of front-line and useful fighters. Only a small portion were old (these consist primarily of Navy/Marine A-4 Skyhawks, which have now been phased out of service).
- The FSU possessed a large proportion of advanced aircraft, though not as large as the U.S. portion.

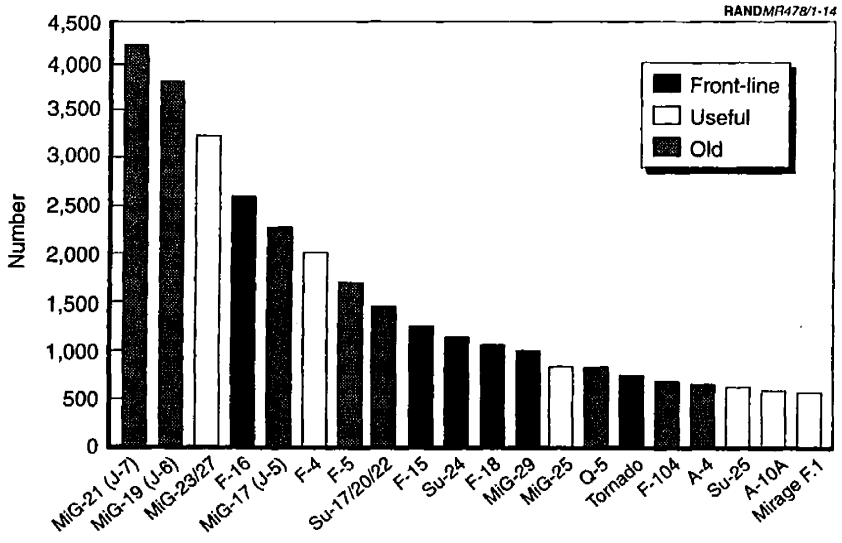

Figure 14—The Top 20 Fighters, 1991

- China's large fighter force in general could be considered almost obsolete.
- About half of Western Europe's inventory was composed of advanced aircraft, but about half of it is old aircraft (such as Italian F-104s, Portuguese G.91s, and Swiss Hunters). This is a surprisingly large proportion, considering the amount Western Europe spent on defense in the past few decades.
- The rest of the world's inventories primarily featured old aircraft, though the Middle East and Pacific regional inventories showed some proportions of front-line fighters.

During the 1970s and 1980s, both the United States and Soviet Union invested heavily in front-line aircraft—Western Europe to a lesser extent. In the rest of the world, the investment was obviously more modest.

Figure 16 provides an overview of the top 30 airpower forces next to the "Big Three." What is striking is the fairly modest number of

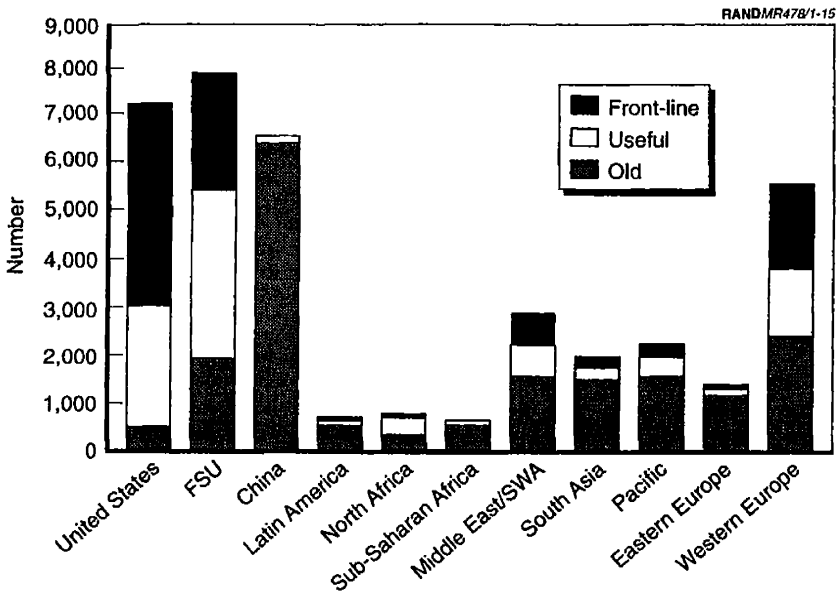

Figure 15—Fighter Distribution, 1991

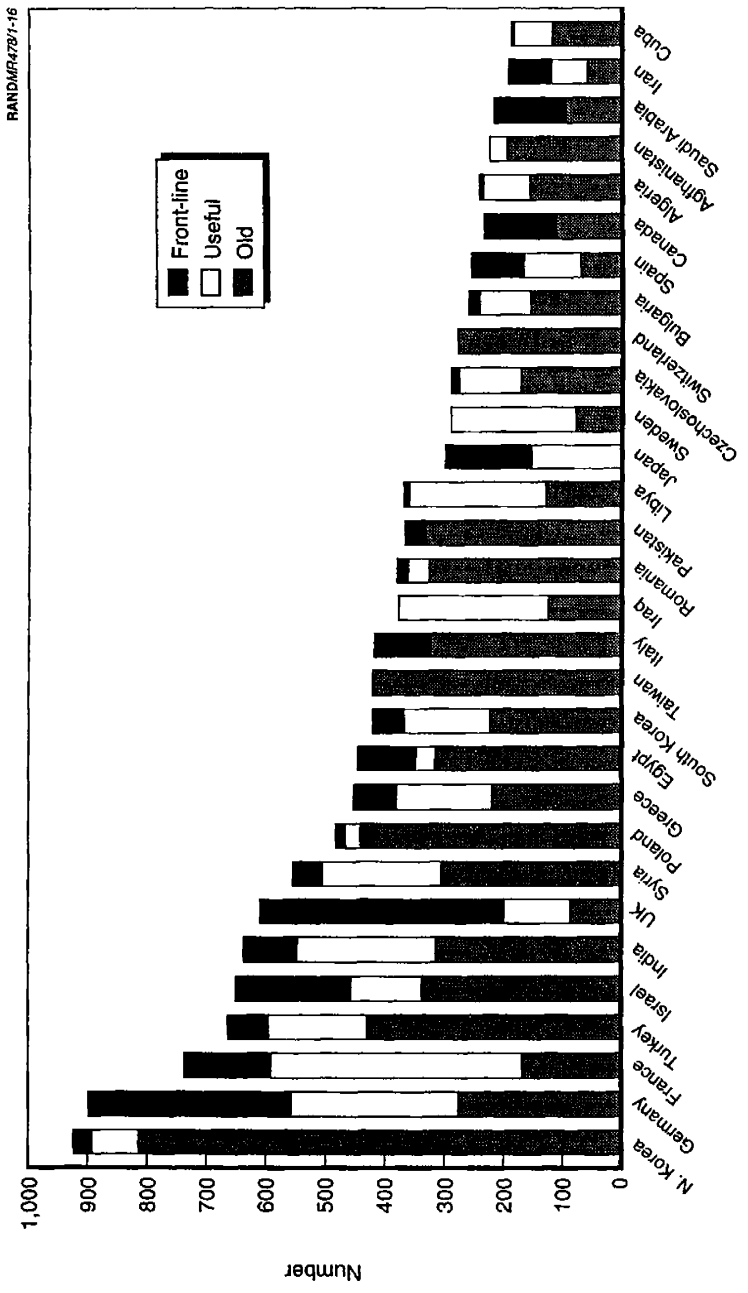

Figure 16—Fighter Inventory by Country, 1991

fighters maintained by these nations compared to the Big Three. Whereas the United States, FSU, and China fielded forces ranging from 6,000–8,000 fighters in total inventory and accounted for about a third of the world's total inventory, the next 30 air forces ranged in size from 250–800 fighters, for a total of about a third of the world's inventory. The other one hundred or so airpower forces possessed the remaining third of the world's fighter inventory.

The second striking feature in Figure 16 is the poor modernization position of most of the world's airpower forces. Most possess old aircraft. In general, significant proportions of front-line fighters are found only among traditional U.S. allies and friends, such as the United Kingdom, Germany, France, Israel, Japan, and Saudi Arabia. Not coincidentally, U.S. allies and friends tend to possess the most powerful economies—something, as we will explore in the next chapter, of great utility when attempting to field capital-intensive airpower forces.

Chapter Five

PERSPECTIVES ON THE FUTURE FIXED-WING BALANCE

We have just described the position in terms of the balance of airpower at the end of the Cold War, when the United States emerged as the world's sole superpower. This chapter analyzes what the prospects are for other nations to stalemate the United States by countering "in kind"—by increasing their emphasis on fixed-wing airpower. To do so, we focus primarily on the economies of the world's nations. Airpower is a capital-intensive form of military power, and fielding effective airpower forces requires a large expenditure of funds. Part of the reason stems from the expense of the aircraft themselves, and part stems from the infrastructure needed to make the aircraft part of an effective warfighting system. We address both of these components in turn and assess the capability of representative nations to make the investments required to produce a first-class airpower force.

RESOURCES FOR AIRPOWER MODERNIZATION

To determine the potential of various nations to modernize their airpower forces, the first step in our analysis was to examine the likely financial resources available. A nation's gross national product (GNP) is the measure of its productive capacity—the sum of the value of goods and services produced. As GNP increases, the discretionary funds of the nation's central government also typically increase—as do the funds available for military spending. In this simple conceptual model, a nation's GNP is the "engine" that drives military spending. Consequently, if nations desire to increase their military expenditures, they typically require an increase in GNP.

There are obviously exceptions to this rule.[1] Nonetheless, this simple model is useful in providing a perspective on the relative potentials for increased military spending.

Figure 17 provides economic data for the period 1979–1989. We examined more recent economic data (see below), but since even rapidly expanding economies grow at fairly low rates, the analysis indicates that the relative positions have changed little since 1989 (if anything, the position of the FSU and its former allies has declined).

The figure illustrates that most of the world's productive capacity resides in the industrial regions. The United States and its allies and

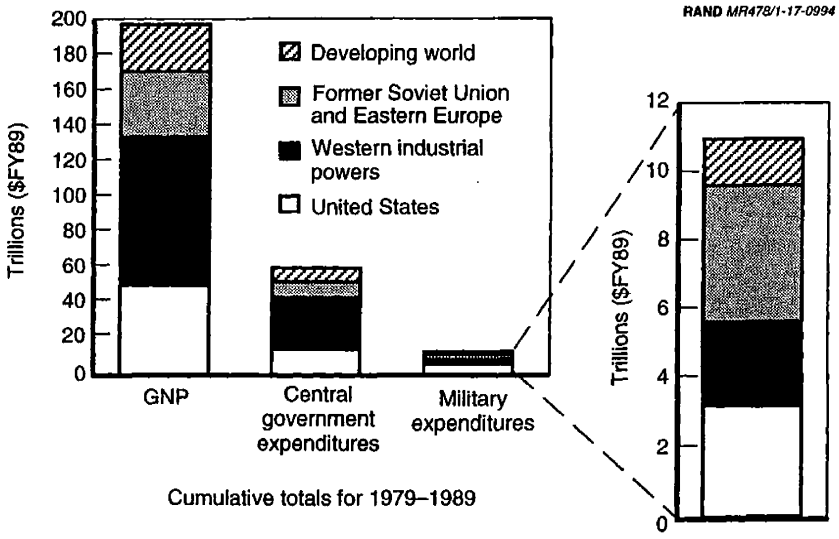

Figure 17—Most of the World's Economic Power Lies in the Advanced Nations

[1]All nations may, if faced with a serious external threat, seek to increase monies spent on defense. Moreover, leaders of authoritarian and totalitarian regimes may have the advantage over leaders of democratic regimes in their control of central government discretionary funds, and could direct that a greater percentage of GNP/central government expenditure be spent on military forces. Over the long run, this may prove counterproductive (by damaging the health of the economy in question), but over the short run it could allow the buildup of significant military capabilities.

friends in the industrialized world, when combined with the former Warsaw Pact countries, produced an astounding 87 percent of the world's goods and services. This fact indicates that most of the world's economic "engine" lies in the hands of the United States, its allies in the Pacific and Europe, and, potentially, the emerging democracies of the former Warsaw Pact.

The powerful economies of the industrial regions guarantee that they have by far the most funds available to their central governments for use in implementing domestic and security policies. Figure 17 shows that 85 percent of the world's central government expenditures occurred in the industrial powers. These nations thus possess the largest "pool" of resources out of which military expenditures can come. Moreover, it is not surprising to see in the figure that these nations, engaged for decades in cold war, accounted for the overwhelming share of global military expenditures. Indeed, the United States alone spent more on its military than the entire developing world (which includes such powers as China and India) combined. The lack of capital available to the developing world obviously will constrain their capabilities to modernize their airpower forces.

PROCURING EFFECTIVE FIGHTER AIRCRAFT

As we have pointed out, most of the world's nations outside the West possess stocks of fairly dated fighter aircraft. To modernize combat inventories, nations will typically employ a mix of two major options. The first is to replace their old fighter forces with new aircraft. The second is to upgrade their current fighters with new systems, such as advanced engines and new avionics.

Procurement of New Fighters

Modern fighters are substantially more expensive than those of older generations. For example, the average cost of a USAF aircraft procured in the 1990s was five times higher than the average cost of an aircraft procured in the 1960s.[2] And fighters in the 1990s are likely to

[2]This was calculated by dividing the total number of USAF aircraft procured in the 1960s, 1970s, and 1980s by the total amount of funds devoted in budgets to aircraft procurement.

cost more than the same fighters in the 1980s. The vast investment made by the United States in the 1980s means that the USAF can well afford, as planned, to go on a fighter procurement "holiday" for at least a decade (though the USN/MC will require continued significant investment to maintain planned force levels). This, combined with decreasing defense budgets, means that procurement rates will decline. And declining procurement rates mean that individual unit costs will increase (since the costs of maintaining the manufacturing lines must be spread over smaller production lots). Similar problems are affecting other nations capable of building advanced aircraft, such as the United Kingdom, France, and Russia. The increasing unit costs will affect all powers seeking to buy advanced fighters.

Exacerbating these problems, particularly for the developing world, are reductions in subsidized arms transfers in the wake of the Cold War. During that long struggle, the superpowers supplied many nations with aircraft and/or financial support for their military forces. In the 1950s, for example, the United States provided a large number of fighters to the nations of NATO to help build up their air forces. Similar transfers to other nations (e.g., Israel, Egypt, etc.) have occurred in more recent years. The Soviets conducted similar deals with such nations as Syria, Iraq, and India, among others. In essence, subsidized transfers of military hardware served as one means to gain political leverage in the Cold War struggle.

In the future, however, the United States and other powers are looking to foreign sales (and the key word is sales, not giveaways) to maintain their defense industrial base. For example, without F-16 and F-15 foreign sales, the U.S. production lines of these aircraft would have to shut down quite soon. Foreign sales have consistently been the mainstay of France's aerospace industrial base (historically, 63 percent of French fighter production has been sold abroad).[3] That nation is looking to do the same in the future with the Rafale advanced fighter. The end result is that foreign powers seeking to build up airpower capabilities are going to have expend significant sums of money in order to do so. Russia has been offering fairly good

[3]See Simon (1993), p. 3.

"deals" on its military equipment, but a MiG-29 still costs over $20 million in hard currency, according to recent sales figures.[4]

Given the large inventory maintained by the new nations of the FSU, Russia in particular, some have raised the concern that these aircraft could be sold at "fire sale" prices, which would certainly increase the potential for nations to modernize at a more affordable rate. But the potential of such a policy is limited for two main reasons.

First, as will be illustrated in more detail below, the collapse of the Soviet Union resulted in a scattering of that power's front-line fighter inventory among the various republics. Russia alone does not possess that many front-line aircraft, and it plans to retain these assets to form the foundation of its future force structure. Accordingly, foreign sales still figure prominently in Russian plans to maintain the faltering aircraft industry.

Second, and perhaps more important, decisions involving fighter fleet purchases are typically made with the long-term future in mind. The aircraft in question, after all, could well serve 20 or 30 years into the future. When aircraft are procured, buyers must consider the stability of the supplier country so that electronic replacement parts, new engines, tires, weapons, and training can be obtained when needed. And this long-term perspective reduces the attractiveness of aircraft from Russia and the former Soviet states. Soviet support has traditionally been of poor quality.[5] Moreover, the ongoing economic and political turmoil in Russia and the various republics—which shows no signs of abating in the near future—must raise serious questions in the minds of prospective buyers about the long-term supportability of these systems.

Upgrading Aircraft Fleets

Modern generations of fighter aircraft currently enjoy service lives of decades (in contrast to World War II fighters, which were often de-

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[4]For some cost figures, see Jack Kelley, "The Russian Arms Market," *USA Today*, May 21, 1993.

[5]See the interview with Major E. Fedoseyev, "Can You Buy MiGs Directly at the Plant?" *Krasnaia zvezda*, June 4, 1992.

signed for only months of service). As noted previously, the long operational lives of fighters have allowed nations to maintain inventory strengths in the face of increasing costs. And by upgrading, nations can attempt to maintain the combat effectiveness of aging platforms. Such upgrades can extend airframe life (by replacing worn frame members and hydraulic and electrical harnesses) and improve performance (by, for example, installing new and more powerful engines).

But it is the integration of new electronics or "avionics" that appears to offer the most leverage. Such equipment can increase pilot or aircrew effectiveness with new cockpit displays and sensors. In addition, new avionics are typically essential before the aircraft can carry new munitions to increase lethality. To deliver laser-guided ordnance, for example, requires the delivery aircraft to have target acquisition apparatus, a laser, and appropriate avionics and subsystems to integrate these systems. To fire an AIM-120 air-to-air missile requires that the aircraft have a powerful radar as well as the avionics and software needed to target and fire the missile. The same goes for many other weapons. Few older aircraft have the necessary avionics and subsystems to employ such weapons.[6] In short, nations cannot simply procure advanced weapons—they must also buy new electronic subsystems and the complex software needed to run them.[7]

But there are limits to the upgrade path. For example:

- As aircraft age, the maintenance burden increases because it becomes more difficult to procure spare parts.[8] Accordingly, in the long run, it can be more cost-effective to buy a modern aircraft than to continue soldiering on with a very old one.[9]

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[6]In addition, a wide range of weapons separation trials must be run—typically a costly affair—to ensure that munitions delivery will not damage the delivering aircraft.

[7]For some specifics of the modifications proposed to two key fighters—the MiG-21 and the Northrop F-5—see Barrie and Velovich (1994), pp. 23–28.

[8]For those nations possessing old Soviet aircraft, this could prove a particularly vexing problem given the fragmentation of the Soviet aircraft industrial base.

[9]For example, suppliers of certain components used in older aircraft may no longer be in business. Accordingly, new production contracts must be let.

- Even with upgrades, an old aircraft will still be an old aircraft and could remain extremely deficient compared to more modern fighters in such important areas as range, payload, maneuverability, and fighting ability. For example, an upgraded F-4, MiG-23, or Mirage III will still not provide the aircrew with good visibility to the rear (and hence improved situational awareness), owing to the basic design of the airframe.
- Even with upgrades, fatigue problems (which can be considerable with high-performance aircraft carrying heavy ordnance loads) and corrosion concerns will eventually force aircraft out of service. Accordingly, planners must carefully weigh the costs involved in upgrading against the anticipated useful service life of the aircraft.

Perhaps most problematic, however, is that the costs can be substantial. In developing cost estimates for new aircraft, the general rule of thumb is that the cost of an airframe is roughly a third of the total cost; engines are responsible for about 20 percent and radar and avionics for the rest.[10] Accordingly, an aircraft upgraded with new engines and avionics could cost approximately 70 percent of the cost of a new fighter—and still possess the drawbacks associated with an aging airframe.

Costs can be increased by such problems as providing adequate cooling for electronic systems, requirements for increasing onboard electrical power generation capabilities, cutting through structural members to route cables, and the like. As India's air force has found in its tentative plans for upgrading MiG-21s, for example, a full upgrade could cost as much as the procurement cost of recently manufactured MiG-21s![11]

Given the advanced age of many of the airframes found throughout the world, it remains uncertain whether the upgrade path will prove

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[10]For example, the cost of the avionics in the F-100A amounted to $225,000 in FY87 dollars. The cost of the avionics in the F-15A came to over $5 million in same-year dollars. See Large, Barbour, and Mills (1988). A ship-set of LANTIRN pods for an F-16, which provide this aircraft with the capability to deliver laser-guided weapons at night and under the weather, costs about $4 million (in FY93 dollars). See Stanley and Liberson (1993).

[11]See Wollen (1992), p. 5. Also see Spellman (1992), p. 26.

a viable option for the long run. It could certainly provide some nations with valuable modernization breathing space as they develop longer-term plans. But it remains unclear how cost-effective upgrading will be should a nation desire to build a first-class airpower force.

FUTURE GLOBAL FIGHTER FORCES

To assess the fighter modernization potential of the top 50 world powers (ranked in terms of military spending), we examined the relative strains that fighter procurement would place on individual economies. Summary points are provided below; details of the analysis are contained in the Appendix.

For purposes here, we will focus first on "the Big Three" and then turn to the other top powers. The analysis of the future position of the Big Three was guided to some extent by the economic findings, but given the importance of understanding the relative airpower balance among these three powers in the future, we conducted additional research on current status and plans. We also provide an overview of other top airpower forces' modernization prospects.

Figure 18 displays our best estimate of the future fighter inventories of the world's three largest airpower forces. What is striking is the powerful potential position of the United States—in both quantitative and qualitative terms—the substantial decline of the FSU, and the continued poor position of China in terms of modern aircraft. This observation, however, should be counterbalanced by the uncertainties associated with making point estimates for something as uncertain as force structures ten years hence. Accordingly, some insights into how we arrived at these estimates are useful in order to inform the reader's judgment as to their veracity.

The Former Soviet Union

The disintegration of the Soviet Union into a welter of republics has shattered that nation's powerful airpower fleet into a set of smaller forces. Based on the most recent *Military Balance*, Table 1 provides an overview of the various republics' strengths by fighter type in 1994. Only two of the new nations field air forces of any significance:

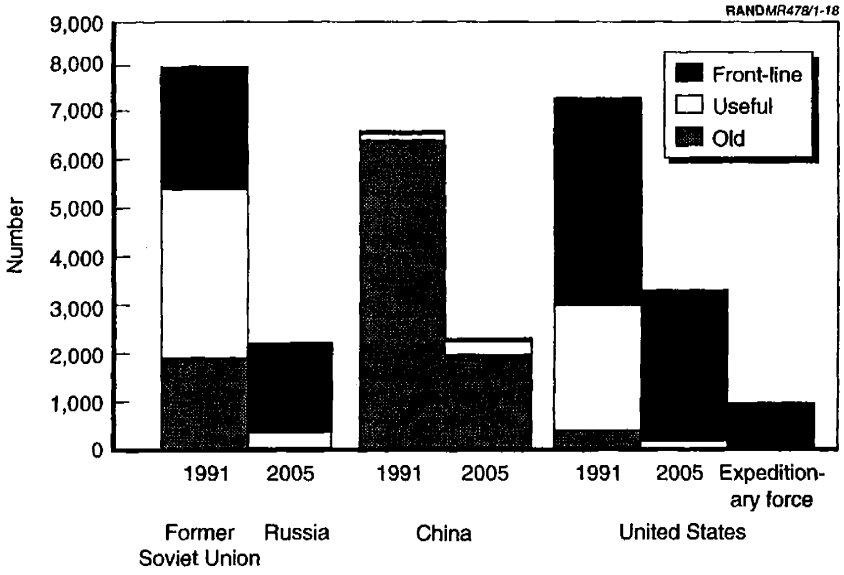

Figure 18—Fighter Forces of the Big Three, Circa 2005

Ukraine and Russia. Ukraine's fighter force is larger than any nation next to the Big Three. It also is quite modern. However, the Ukraine air force suffers from a range of problems, not the least of which is access to spare parts. Most of the Soviet aircraft industry for fighter production is located in Russia—and given the ongoing frictions between Russia and Ukraine, major uncertainties must remain about the latter's ability to maintain any sort of effective force.[12]

The Russian fighter force remains large, but it suffers from a range of problems: low morale, low flying hours (about 40 hours per year per fighter pilot), recruiting problems, housing problems, spares difficulties, and financial difficulties.[13] Currently, the Russian air force plans to greatly reduce the size of its operations in order to consolidate its position—the stated plans are to retire all but the most mod-

[12]See the comments of Colonel General Yevgeniy I. Shaposhnikov in Sergei Kuznetsov, TASS dispatch, February 14, 1992.

[13]For an overview, see Lambeth (1994), pp. 50–53.

Table 1

Fighter Forces of the Former Soviet Union, 1994

Fighter Type	Russia	Ukraine	Belarus	Georgia	Moldova
MiG-21	130	0	0	0	0
MiG-23/27	2,020	125	73	0	0
MiG-25	535	880	65	0	0
MiG-29	430	194	84	0	31
MiG-31	330	0	0	0	0
Su-15	300	99	0	20	0
Su-17/22	545	0	9	0	0
Su-24	740	248	42	0	0
Su-25	340	34	99	20	0
Su-27	390	50	25	0	0
Total	5,760	1,630	397	40	31
Percentage that are front-line	33%	30%	38%	0%	100%

SOURCE: *The Military Balance, 1993–4*, London: International Institute for Strategic Studies, 1993. Counts include naval and air defense aviation, as well as trainers.

ern aircraft from service (e.g., retain Su-27, MiG-29, MiG-31, and Su-25).[14]

Plans are also being laid to procure additional variants of the Su-27 as well as a new fighter, but the range of problems facing the Russian air force raises questions about the viability of future procurement. The Russian aircraft industry is just ticking over—and thus totals shown are unlikely to increase much beyond those indicated on the

[14]Dr. Benjamin Lambeth of RAND is writing a detailed study on the Russian air force as part of the overall study effort, and we are indebted to him for materials on current Russian air force thinking and plans. Declared Russian frontal aviation plans are to retire all MiG-23, MiG-27, and Su-17 aircraft and base the new force structure on the MiG-29, Su-27, Su-25, and Su-24. This is reported in Levin (1992), p. 14. For additional insights, see the following: interview with Colonel General Yevgeniy I. Shaposhnikov, "The Air Force Today and Tomorrow," *Aviatsiia i kosmonavtika*, No. 8, August 1990, p. 2; remarks of General Deneikin in "Russia to Scrap 2,000 Aircraft," *Flight International*, March 31–April 6, 1993, p. 5; and the interview with Kokoshin by Vyacheslav Terekhov and Viktor Akimov, *Interfax*, December 3, 1992.

chart unless there is a dramatic turnaround in the health of the Russian economy.[15]

China

The People's Liberation Army Air Force (PLAAF) and China's naval air arm also face a serious modernization problem. To put this in perspective, for China to replace its entire fighter force with more modern aircraft over the next decade would require it to build or purchase roughly about 600 fighters each year for ten years—a average rate of procurement about 50 percent higher than that maintained by the United States during the last thirty years of the Cold War.[16] Moreover, the PLAAF faces a serious block obsolescence problem in that the bulk of the force—over 3,000 aircraft—is composed of J-6s (Chinese-built MiG-19s). These aircraft are not only operationally obsolescent, they are also encountering service-life problems.

In many respects, China's future force structure will be a product of J-6 retirement phasing combined with production rates for replacement aircraft. The Chinese have the capacity at present to produce three major fighter types as replacements: The J-7 (a Chinese-built MiG-21), the J-8 (an indigenously designed air defense aircraft), and

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[15]For example, deliveries of MiG-29s and Su-27s were suspended in 1993. Although there are no plans to revive MiG-29 production (at least to meet Russian needs), the halt in Su-27 production is temporary, since Russia plans to base its future fighter force largely on variants of the Su-27. But the prospects of additional procurement are limited. Simply feeding and housing personnel is eating up a greater and greater percentage of the Russian defense budget—and thus reducing procurement accounts. In 1990, 36 percent of the defense budget went to housekeeping and social amenities. In 1991, this accounted for 50 percent of the budget—in the first quarter of 1992, 70 percent. See Lieutenant Colonel O. Vladykin's interview with Lieutenant General V. Vorobyev, "The Military Budget: Priority for Social Needs," *Krasnaia zvezda*, February 4, 1992. Also see the interview with the deputy commander in chief, Anatoly Malyucon, in which he states that only a handful of combat aircraft had been ordered in 1993 (interview with Petr Butowski, "Flying in the Face of Adversity," *Jane's Defense Weekly*, April 17, 1993, p. 15).

[16]The United States from 1960 to 1992 procured on average 430 Air Force, Navy, and Marine fighters each year from a much more powerful economic base. Aircraft counted include F-105, F-111, F-4, A-7, A-37, F-15, A-16, F-117, and A-10 for the USAF; A-4, A-6, F-4, F-8, A-7, AV-8, F-14, and F-18 for the Navy and Marines. (Data provided by Dr. Kevin Lewis of RAND.) See Lewis (1993); see also Lewis (1990), pp. 39–40.

the A-5 (a medium attack aircraft).[17] None could be considered an advanced aircraft—the MiG-21/J-7 first flew in 1955, the J-8 in 1969, and the A-5 in the mid-1960s. The estimates employed in Figure 18 assume current production rates for these various systems.[18]

Obviously, increases in production rates could raise overall Chinese fighter totals. But regardless of the total PLAAF/naval aviation force size, what is striking is the lack of modern aircraft. The Chinese recently arranged to procure 72 Su-27 Flankers from Russia—and discussions continue about other types such as the MiG-29 and MiG-31.[19] But to procure substantial numbers of such systems, the Chinese have long emphasized indigenous production. Given the history of Chinese manufacturing efforts, even a concerted effort now to begin license-built production probably would not result in any substantial numbers of front-line fighters in the early part of the 21st century.[20]

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[17]The Chinese have also developed the FB-7, a two-engined fighter-bomber, for the navy. The first two prototypes were rolled out in 1988. However, the lack of a jet engine manufacturing plant to power this aircraft raises serious questions about the future role the FB-7 could play in augmenting the Chinese fighter force structure.

[18]The following assumptions regarding service life were employed: J-5 (25 years), J-6 (28 years), A-5 (28 years), J-7 (25 years), J-8-1 (15 years), J-8-2 (25 years), Su-27 (30 years). We also employed the Institute for Defense and Disarmament Studies' estimates of production rates of 135 aircraft per year (with 60 of those scheduled for export). Estimates for Chinese fighter strengths are obviously uncertain given the limited sources available. We thank Jon Cohen of the Institute for Defense and Disarmament Studies for making his force structure estimates available to us (see J. Cohen, 1994). These data were adapted and refined by Glenn Krumel and Ken Allen, who will report their findings on the PLAAF in more detail in a forthcoming RAND publication.

[19]See "U.S., French Fighter Sales to Taiwan Nudge Mainland China Closer to Russia," *Armed Forces Journal International*, January 16, 1993, and Ackerman and Dunn (1993). Also see "Flanker Sale Stalls as China Seeks New Deal," *Jane's Defense Weekly*, January 22, 1994, p. 3.

[20]For example, it took six years for the Chinese to move from prototype to serial production of the MiG-19. For the MiG-21, the Chinese took almost 15 years to go from prototype to serial production. For indigenously designed aircraft, the history is much worse. For example, the first prototype of the J-8, a modified version of the unsuccessful Mikoyan Ye-152A Flipper, first flew in 1969, but was not validated for production until 1979. Only 50 were built. A modified version, the J-8-2, began entering service in the 1990s. Thus the front-line interceptor of the PLAAF consists of a modified version of an unsuccessful 1961 Soviet design. See "J-8 and J-8 II Finback," *World Airpower Journal*, Fall 1990, p. 18.

In terms of the airpower balance, the 1990s should provide some strong indications of future Chinese intentions and capabilities. If China proves capable of putting together the industrial infrastructure to manufacture modern aircraft—and if its economy continues to improve—that nation could emerge as a more substantial player in terms of global airpower balance as the 21st century proceeds. But such a policy would require a very long and concerted effort on the part of the Chinese.

The United States

Under the terms of the Bottom-Up Review, the United States plans to maintain a force of 20 fighter wings, 12 carriers, and 3 Marine air wings. This will require a total inventory of approximately 4,200 fighters.[21] Given plans to retire A-6s, F-111s, and F-4s within the next decade, the entire force, with the exception of remaining Harriers, will soon consist of "front-line" aircraft. It should be noted, of course, that budgetary pressures will continue to exert their influence—and the overall U.S. inventory could certainly be lower. But the figure illustrates what is projected under current plans.

One additional column (labeled "expeditionary force") is shown next to the U.S. totals in Figure 18. U.S. airpower force sizing is the result of current U.S. national military strategy, which calls for a two-conflict capability—that is, the capability to prosecute two concurrent theater wars that may erupt sequentially but at times must be prosecuted simultaneously.[22] The bar represents the number of fighters the United States currently plans to deploy to a regional conflict: 10 fighter wings, 3–4 carrier air wings, and a Marine air wing—a total of roughly 1,000 fighter aircraft.

The future U.S. force is supposed to provide two such expeditionary forces (along with ground forces, of course), but questions remain about the ability of the force structure to generate two such forces

[21]Assuming 20 USAF fighter wings of 72 aircraft, 12 carrier air wings (of 50 fighters each), and 3 Marine air wings of 100 fighters each and using a ratio of 1.8 total fighters for each deployed fighter results in a total estimated inventory of about 4,200 aircraft.

[22]See Chapter Six for additional comments on this strategy. Discussion of the two-conflict strategy is contained in Bowie et al. (1993), pp. 5–6.

(not to mention deploying and supporting them). In all likelihood, the second force, if required, would be smaller. In general, planning for a two-conflict force provides a measure of insurance in the event a larger power or coalition arises in the uncertain future. But the U.S. airpower force is primarily focused on dealing with regional powers, a subject to which we now turn.

The Other Top 30 Airpower Forces

Figure 19 shows the position of the other top 30 air power forces next to the Big Three with one additional data point added: The U.S. expeditionary force. As can be seen, the U.S. force compares most favorably in terms of both quality[23] and quantity. But how will it fare in the future?

In general, nations with larger proportions of front-line aircraft have the potential to modernize with smaller relative strains on their economies. The better position a nation enjoyed in terms of numbers and modernity at the close of the Cold War, the better position that nation will possess in the future. This situation tends to place the nations of the West—particularly the United States, with its modern force structure and powerful economy—in a highly advantageous position regarding the future airpower balance.

The economic analysis in the Appendix suggests that it is extremely unlikely that many developing nations will be able to procure highly advanced expensive aircraft (along the lines of an F-15, Su-27, Tornado, or Rafale) or even less-expensive aircraft (such as an F-16 or MiG-29) *without greatly reducing the size of their air forces* (that is, replacing two or more current fighters with a single new one).

The reasons are quite straightforward. The developing world currently possesses a large number of old fighters and only limited sums of capital. Modern aircraft are substantially more expensive than previous generations, and a variety of factors indicate that individual unit costs will increase in the 1990s. The nations with the strongest potential for replacing their existing older force with new assets are

[23]Depending on the year in which the conflict took place, some portions of the force could be "useful" as opposed to "front-line." Within a decade or so, however, the entire force with the exception of Harriers will be front-line.

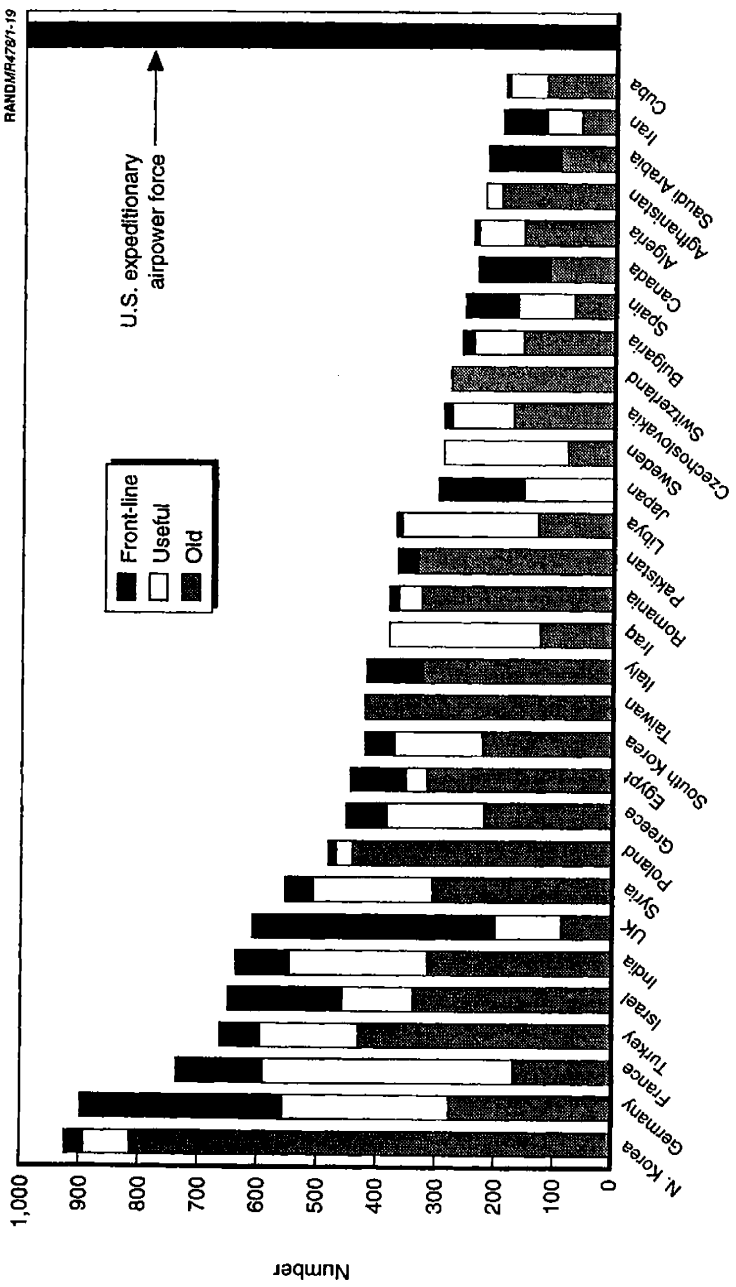

Figure 19—The Other Top 30 Airpower Forces at the End of the Cold War

located in the Pacific region and Southeast Asia (see the Appendix for details). Accordingly, should the developing world attempt to procure new aircraft, it appears that the end result would be airpower forces of smaller size.

For illustrative purposes, Figure 20 provides an overview of perhaps a worst-case scenario, one in which the top 30 airpower nations procure new front-line fighters to replace their old and useful aircraft on a 1-for-2 basis over the next decade. Overall, fighter forces will decline in size. It should be emphasized that the calculations laid out in the figure are illustrative only—for example, the chances of North Korea or Cuba modernizing at these rates are extremely small.

Another option for these air forces is to upgrade existing fleets of aircraft. As noted above, the effectiveness of this policy remains uncertain and would be highly dependent upon the types and expected service lives of aircraft maintained in current fleets. Moreover, since the subsystems that make the most difference in performance—engines and avionics—are the primary cost drivers, upgrades could require the same levels of investment as those required to replace fighter fleets on the 1-for-2 basis outlined in Figure 20.

Given the fairly elderly nature of many of the platforms in the developing world, as aircraft continue to age and are forced from service due to fatigue problems, nations that choose the upgrade path will decline in size in any case. The upgrade option would result in "kicking the can" a little further down the road—and would not solve the long-term modernization problems facing most of the world's powers. But as noted earlier, it could prove crucial in providing many of the world's powers with adequate breathing space to modernize more affordably while maintaining end strength.

IMPLICATIONS

Whether potential adversaries procure new fighters or upgrade existing ones, the presence of larger numbers of more capable aircraft, particularly modern air superiority or multirole types, means that the position of the United States would deteriorate. Other nations, after all, have the option to focus their limited airpower resources on the air defense role in order to deny or delay U.S. forces control of the air.

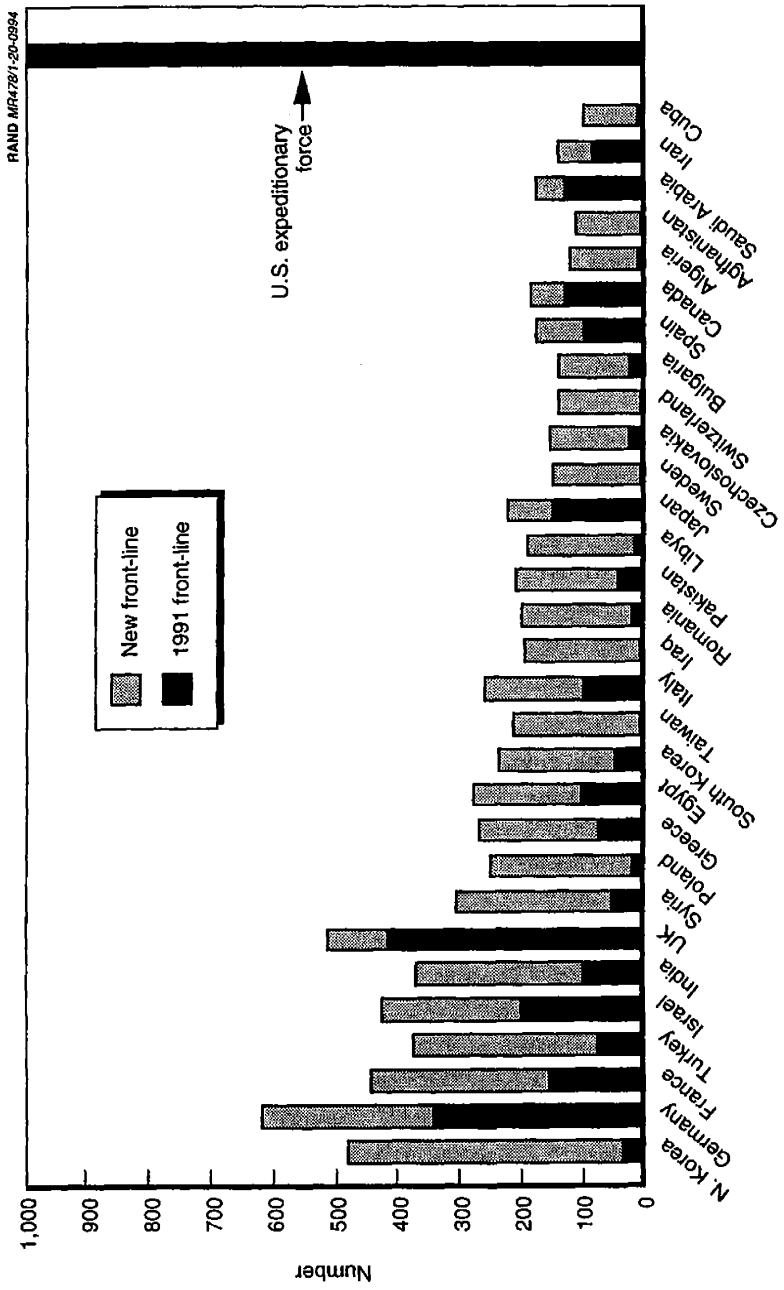

Figure 20—Potential Future Fighter Forces, Circa 2005

In contrast, the United States must maintain a much more diverse and flexible airpower force.

At the close of the Cold War, the United States enjoyed a qualitative and quantitative advantage over all other nations. As other nations replace old systems with front-line systems, it is likely that the United States will retain its quantitative edge. But its *qualitative* edge will decline unless modernization is pursued as well.

The potential implications are illustrated in Figure 21, which illustrates the exchange ratios that the United States' most advanced air superiority fighter, the F-15C armed with the active radar-homing missile (the AIM-120), might achieve against the following opponents:

- A Mirage 2000 armed with a semi-active missile (which requires the launching fighter to keep the target illuminated);
- An Su-27 Flanker armed with an active missile (thus permitting the launching fighter to "shoot and scoot";
- A "future threat" that consists of a current fighter using straightforward radar cross section reduction techniques, a better radar, and an AIM-120 missile.

These exchange ratios were calculated using a highly sophisticated computer model (TAC BRAWLER) that simulates engagements of four aircraft on each side.[24]

Given the importance of minimizing casualties and controlling the air, maintaining a qualitative edge remains crucial. For example, in the 1967 Arab-Israeli War, the Israeli air force achieved a remarkable and resounding victory against adversaries that outnumbered it and possessed equipment of relatively similar capabilities. But what is often not realized is that Israel lost 20 percent of its total inventory of fighters and 10 percent of its pilots (either dead or captured) in the course of that conflict.[25] Given the political symbolism attached to

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[24]The erosion of the U.S. advantage illustrated in the declining exchange ratios is a function of improved missile technologies, radar and avionics, and radar cross section reductions. See Shaver, Harshberger, and Crawford (1993).

[25]See Yonay (1993), p. 265.

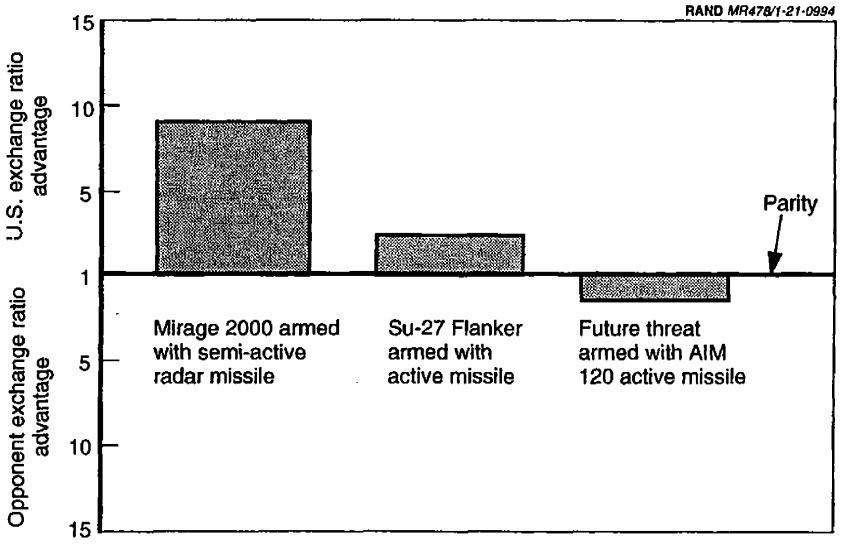

Figure 21—F-15C with AIM-120 Versus Future Threats

U.S. airpower, any such losses inflicted on the United States, particularly in the early stages of combat, could have important military, strategic, and political effects. And they could be avoided in part through prudent modernization.[26]

CREATING AN EFFECTIVE AIRPOWER FORCE

The previous part of this chapter discussed potential fighter modernization prospects for various nations. But simply purchasing aircraft does not create an airpower force—a variety of investments must be made to create an effective fighting force. To make the most effective use of advanced or upgraded platforms requires that nations make a broad range of investments in such areas as munitions; command, control, communications, and intelligence infrastructure; logistics infrastructure; and training.

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[26]For additional thoughts on this complex subject, see Shaver, Harshberger, and Crawford (1993).

Munitions

Modern munitions are critical to enhancing the lethality of airpower. But modern munitions are expensive. Whereas a 2,000-pound general-purpose bomb costs around $3,000 per round, the laser guidance kit for that same round may cost $50,000 (exact costs, of course, depend on the size of production runs). The increase in lethality is clearly worth the investment when looking at the total costs involved in putting a sortie over a target, but this still does not obviate the need to make the additional investment. More autonomous weapons, such as the AIM-120 missile, HARM missile, or standoff weapons, can cost in the half-million-dollar range. To put this in perspective, consider an F-15C with a full load of eight AIM-120 missiles. The cost of the ordnance represents roughly 1/8 the cost of the aircraft.[27] And multiple munitions loads must be procured to ensure that each aircraft is appropriately armed on each sortie. Finally, as noted previously, aircraft must be equipped with the appropriate avionics and subsystems to employ such weapons.

Command, Control, Communications, and Intelligence

To obtain maximum effectiveness in combat, fighters and bombers must be employed using the most effective operational strategies and against key targets. This requires a command, control, communications, and intelligence (C3I) system. In general, surveillance systems, such as airborne radar platforms, electronic snooping assets, and similar systems flying in space, provide information. These data are then analyzed and sent to the employing commanders to give insights into enemy activities and intentions as well as the effectiveness of past operations. Commanders use the information to develop appropriate responses and to task friendly forces. The latter activities require extensively developed communications systems, which in turn must be rendered as secure as possible from enemy jamming, attacks, and eavesdropping.

Intelligence systems are expensive. For example, JSTARS aircraft, which employ a radar system to locate enemy targets and vehicles

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[27]This assumes an AIM-120 costs $700,000 and an F-15C about $40 million in FY93 dollars.

deep inside enemy territory, and AWACS aircraft, which employ a radar system to detect and track enemy and friendly aircraft, are among the most expensive aircraft ever built. The cost is not a product of the airframe, but of the complex software and radar technology carried. Similarly, space assets are extremely expensive. This is due in part to the high cost of delivering a payload into space and in part to the high cost of the advanced technology needed to miniaturize functions and thus minimize weight.

Considerable funds must be expended to ensure that commanders are educated in the doctrine and strategies of modern warfare so that they can employ their forces to maximum effect. Without that education, for example, it is unlikely that the United States could have developed the air attack plan that proved so devastating to Iraq in the Gulf War.

Finally, commanders and intelligence must be linked together through secure communications networks. These systems are perhaps the only element of the C3I equation that has come down in price (at least in terms of cost per unit of data transmitted). They can also be procured as part of nation-building efforts aimed at improving the infrastructure.

Logistics

Since airpower assets are so expensive, it is crucial to extract the maximum out of each platform. This requires funding logistical accounts to ensure the maintenance of sufficient stocks of spares, and it also requires continuous and highly technical training to ensure that skilled personnel are available to repair the various systems. This enables air commanders to gain the maximum sortie rate out of aircraft and thereby extract each one's maximum combat potential. This sort of funding adds to the cost.

Training

Realistic training maximizes combat potential. It has long been an article of faith in the United States and other first-rate airpowers that nothing can substitute for realistic and demanding training. But it is not costless to maintain a sufficiently high operational tempo to keep

personnel appropriately trained. Flying advanced jet aircraft is expensive. More training hours mean that more spare parts are required. With additional training, more aircraft will crash, necessitating the procurement of sufficient numbers of aircraft to maintain desired combat strengths. And to gain the maximum benefit, instrumented training ranges are needed, which are also quite capital-intensive items.

WHAT DOES A FIRST-RATE AIRPOWER FORCE COST?

All the items discussed above—advanced or upgraded aircraft, advanced munitions, an effective C3I system, sufficient logistics, and training—would require a nation to spend additional funds to field an advanced airpower force that could seriously challenge the United States. To provide a perspective, we first analyzed the kind of air force a nation might want to field, examined what the annual cost of such an air force might be, and compared that to the military spending of the top-spending powers in the world.

A first-class airpower force, particularly one aimed at denying the use of its home airspace to the United States, should possess a range of critical capabilities:

- An airborne early warning fleet to enhance air defense capabilities;
- Sufficient stocks of advanced munitions to maximize lethality;
- Realistic training;
- Some airlift and tanking capability to maximize flexibility;
- An integrated C3I system;
- A logistics system capable of generating high sortie rates;
- A reasonably modern force of fighters.

When looking around the world, only three air forces (besides those in the United States and FSU) offer such capabilities: the United Kingdom's Royal Air Force (RAF), the French air force, and the Israeli air force.

Figure 22 illustrates the total individual defense expenditures in 1989 of the top 45 powers (ranked in terms of military expenditure) after the United States and the FSU. Overlaid on these totals are estimates for that year on the *annual* expenditure required to support the three air forces in question. The figure illustrates that few countries of the world spend as much on their entire military as the British and French spend on their air forces alone.[28]

The estimates of Israeli air force expenditures appear far more reasonable, but balanced against this must be considerations of the uncertainty associated with such estimates.[29] Moreover, in many respects, Israel's situation is the result of extremely special circumstances. Some of the reasons the Israelis are capable of maintaining a high-quality air force at such relatively modest cost are the following: (1) large portions of their personnel are provided through conscription, while the British and French (as well as the United States) rely more heavily on volunteers, which increases personnel expenditures; (2) the Israelis do not maintain as large and capable a set of airlift and tanking capabilities as the British and French; (3) some Israeli combat equipment is provided free of cost;[30] and (4) Israeli defense budgets appear to use some "unusual" accounting procedures—and may in fact understate true spending.[31]

It is therefore difficult to imagine that nations other than those now possessing large and capable air forces could reasonably acquire such forces. To field more capable airpower forces, they would need to greatly increase their defense spending. At present, it is difficult to

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[28] Details on British and French defense spending are contained in Nation (1992).

[29] Israel does not provide much detail on its defense spending. Only in 1994 did Israel provide a broad overview of total defense spending—about $7.4 billion in U.S. FY94 dollars. $4.86 billion was provided by Israel, $1.8 billion was U.S. military assistance, and about $0.5 billion was foreign sales. Costs of military operations (e.g., in Lebanon) are not included, nor are some of the monies employed for defense industry modernization or civil defense programs—which could total $1–2 billion more. Spending on individual services is not provided. For purposes here, we assume half of the budget was provided to the Israeli Air Force. See Kaminer (1994), pp. 20–21.

[30] In the wake of the Gulf War, Israel has been given two submarines from Germany, three Patriot missile batteries, and 71 fighter aircraft. These assets were worth about $3 billion. See Kaminer (1994), pp. 20–21.

[31] For example, the costs of ongoing operations are not included in defense spending accounts. How these are defined remain uncertain.

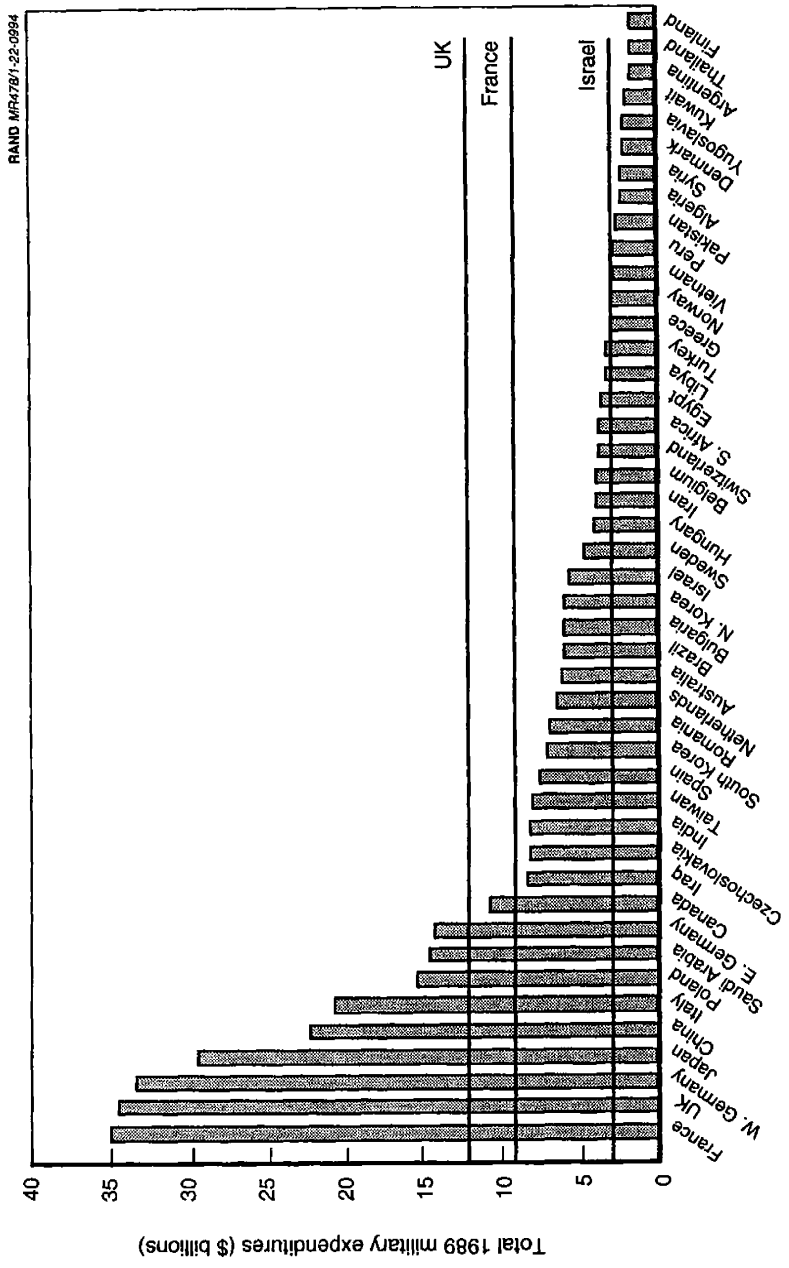

Figure 22—Prospects for Building a Capable Air Force

ascertain where defense budgets are currently heading. The data employed in this analysis end in the year 1989. Since that time, defense spending increased substantially in 1990 and 1991 for many important nations due to the Gulf War—and then dropped. But such little time has passed since that conflict that it is difficult to predict future directions in defense spending. To date, in most nations, actual spending has declined or remained fairly steady in the period 1992–1993 (the key exceptions being nations on the Pacific Rim, such as China, Taiwan, Japan, and some of the nations in Southeast Asia).

In the end, a powerful airpower force requires the support of a strong economy. We accordingly analyzed one additional and important factor. Could strong economic growth produce the central government resources, and ultimately the military resources, to permit nations to field an air force of the caliber of the British or French? Assuming that the non-NATO nations of the top defense-spending nations grow at the phenomenal growth rate that China enjoyed in the 1980s (a truly optimistic upper bound), this in turn would allow defense budgets to increase at the same rate (roughly 10 percent per year).

The results of such growth are shown in Figure 23. Only a few nations outside of the NATO alliance would be able to afford an air force along the lines of the British or French. Japan currently fields a large and modern air force, and with exceptional economic growth or an increasing proportion of government spending on defense, it could field a very powerful force indeed. China has the potential at present to field a medium-sized modern air force, but not one as large as it currently fields (and its modernization prospects are rendered more uncertain due to difficulties with indigenous modernization programs, as we have discussed). Saudi Arabia, which has invested heavily in airpower in recent decades, also has the potential to field a powerful force (but sustained problems with declining oil prices cast doubt on its ability to generate and sustain such growth). Though Poland shows on the chart, we are reluctant to make judgments about that country because of the uncertainties involved in calculating former Warsaw Pact economic and military expenditure data.

Beyond these nations, very few appear likely to grow their way towards affording a high-quality air force. In addition, in the devel-

oping nations such investment would require spending a very large proportion of the defense budget on airpower (when the historical pattern for many such nations has been to invest in land forces, which are cheaper, useful for nation-building, and often essential for maintaining regimes in power).

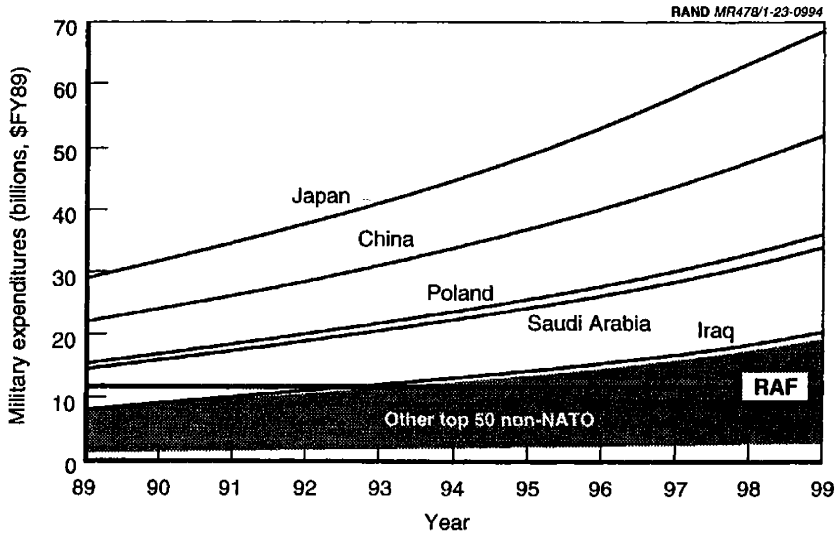

Figure 23—Military Spending Growth of Non-NATO Nations Assuming Chinese GNP Growth Rates

Chapter Six

BALLISTIC AND CRUISE MISSILES

The analysis thus far has not painted a very favorable picture of the potential for nations to challenge the United States with fixed-wing airpower. This chapter explores the potential of a less traditional form of airpower—ballistic and cruise missiles—to shift the balance, and it assesses the implications of such a strategy. Both types of weapons were first employed in conflict during World War II and received new prominence in the Gulf War.

BALLISTIC MISSILES

Since World War II, ballistic missiles have been employed in the 1973 Arab-Israeli war, the 1980–1988 Iran-Iraq War, the 1991 Gulf War, and, at the time of this writing, the ongoing Afghan and Yemeni civil wars. In the Gulf War, Iraqi Scuds proved to be a formidable weapon in political and strategic terms. For example, although the Scud attacks did not cause any militarily significant damage, they threatened to bring Israel into the war (thus raising the specter of splitting the allied coalition), diverted substantial airlift resources (to deploy Patriot defensive systems), and caused a large number of allied sorties to be diverted into fairly unsuccessful "Scud-hunting" missions. Moreover, there is growing evidence after the conflict about the Patriot's limited effectiveness and the inability of offensive strikes to destroy Iraq's missiles and weapons of mass destruction. This highlighted the vulnerability of U.S. and allied forces to attack throughout

the war.[1] The Scud experience has naturally heightened concern about the proliferation of these weapons.

Accurate counts of ballistic missiles currently fielded are not available, but it appears that the United States and FSU still dominate the field. The United States and FSU field several thousand large intercontinental ballistic missiles. Moreover, both powers also field hundreds, perhaps thousands, of shorter-range systems (such as the U.S. Army's ATACMS).

Numbers for other powers are uncertain. China is reported to field 14 ICBMs and 60 or so intermediate-range missiles. For other nations, the most popular missile remains the Scud (and derived variants). The former Soviet Union, it is generally believed, has manufactured from 5,000 to 10,000 Scuds, but it is unknown how many of these have been exported. The North Koreans are believed to have the capability to manufacture about four Scuds a month and are developing longer-range missiles.[2] In addition, many other countries have the capability to manufacture these weapons. This is illustrated in Table 2, which provides an overview of ballistic missile capabilities in the developing world.

Though detailed estimates are difficult, it appears that the raw number of ballistic missiles deployed across the planet is fairly low if the United States and the former Soviet Union are not included. Indeed, whereas counts of aircraft, SAMs, and helicopters routinely yield numbers in the hundreds per nation, similar counts of ballistic missiles, where available, typically yield a few dozens. These estimates appear to be reflected in Pentagon thinking as well; the Bottom-Up Review, for example, lays out scenarios in which a regional aggressor might possess between 100 and 1,000 ballistic missiles.[3] And while wars have seen literally tens of thousands of aircraft sorties, counts for ballistic missile "sorties" are much lower.[4]

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[1]See Hosmer (1994), pp. 9–12. For some revealing insights on the issues raised by nuclear proliferation, see Millot, Molander, and Wilson (1993).

[2]See Nagler (1992), p. 13.

[3]See Aspin (1993), p. 13.

[4]In the Iran-Iraq War, for example, during that eight-year conflict the two sides fired about 600 missiles at each other; in the six-week Gulf War, the Iraqis fired about 90 weapons. There are two exceptions. In World War II, the Germans fired approxi-

CRUISE MISSILES

In the wake of World War II, the U.S. Air Force and Navy maintained an ongoing flirtation with the cruise missile during the 1950s. The Navy fielded the Regulus, the Air Force the Snark, Matador, Mace, Quail, and Hound Dog.[5] But neither Service displayed any strong and consistent interest in cruise missiles for land-attack operations. This was due to institutional emphasis on fixed-wing aviation combined with concerns over the poor reliability and accuracy of these cruise missiles compared to manned aircraft.[6]

The same constraints did not hold true for anti-ship cruise missiles. The Soviets fielded such weapons starting in the 1950s.[7] Providing guidance for anti-ship cruise missiles proved much easier than for land targets, owing to the limited clutter presented by a surface ship on the open sea. Anti-ship cruise missiles began to proliferate widely following the sinking of the Israeli destroyer *Eilat* in 1967—and perhaps even more following the successful Argentine employment of Exocet missiles in the Falklands conflict in 1982 (where three of five missiles fired struck British vessels).

Improvements in propulsion and guidance technology resulted in U.S. development of far more accurate land-attack cruise missiles in the late 1960s—and the fielding of the nuclear-tipped Air Launched Cruise Missile (ALCM) and a ground-launched derivative in the 1970s and 1980s. But only the U.S. Navy pressed ahead publicly with a conventional variant of its Tomahawk Land Attack Missile or TLAM (though following the Gulf conflict, it was revealed that the USAF had secretly fitted some ALCMs as well with conventional warheads and

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mately 3,000 V-2 ballistic missiles against targets in the United Kingdom and the European continent—in September 1944, their rate of fire averaged about 15 missiles a day; the maximum rate of fire stood at 26 per day in December 1944 (see Irving (1964), p. 306). On the other hand, that conflict saw literally hundreds of thousands of sorties by fixed-wing aircraft. In the Afghan civil war, government forces have reportedly fired about 2,000 Scuds at guerrilla forces over this multiyear struggle (though given the extremely poor accuracy of the Scud, it remains unclear what utility these weapons served).

[5]The Snark, Matador, and Mace were launched from the ground. The Quail was a bomber-launched decoy, the Hound Dog a bomber-launched nuclear-tipped missile. See Werrell (1985), pp. 81–128.

[6]See Werrell (1985), p. 128.

[7]See J. Toomay, "Technical Characteristics," in Betts (1981), p. 32.

Table 2

Ballistic Missiles of Developing Countries

Country	Range Category (km)					Supplier
	30–250	300	500–650	900–1,200	>1,500	
Afghanistan		Scud B				USSR
Argentina	Alacran			Condor 2		Indigenous
Brazil	MB/EE-150 SS-150	MB/EE-300 SS-300	MB/EE-600	MB/EE-1000 SS-1000		Indigenous Indigenous
China	B-610	M-11	M-9	M-?	CSS-2	Indigenous
Egypt		Scud B Scud B	Scud C	Vector		USSR North Korea franchise Indigenous (Condor technology)
India	Prithvi				Agni	Indigenous
Iran	Iran-130	Scud B Scud B	Scud C			USSR North Korea franchise Indigenous
Iraq		Scud B Scud B	Scud C Al Hussein	Al Abbas Badr 2000	Al Aabed	USSR North Korea franchise Indigenous (Scud technology) Indigenous (Condor technology)
Israel	Lance		Jericho 1		Jericho 2	Indigenous United States

Table 2—continued

Country	Range Category (km)					Supplier
	30–250	300	500–650	900–1,200	>1,500	
Libya	SS-21	Scud B	Scud C M-9	Al Fatah		USSR North Korea China Indigenous
North Korea		Scud B	Scud C	No Dong 1	No Dong 2	Indigenous
Pakistan	Hatf 1	M-11 Hatf 2				China Indigenous
Saudi Arabia					CSS-2	China
South Africa			Arniston			Indigenous (Jericho 1 technology)
South Korea	NHK-1, -2 Lance	NHK-A				Indigenous United States
Syria	SS-21	Scud B Scud B	Scud C M-9			USSR North Korea China
Taiwan	Green Bee			Sky Horse		Indigenous
Vietnam		Scud B				USSR
Yemen	SS-21	Scud B				USSR

SOURCE: Dr. Robert Nagler, *Ballistic Missile Proliferation: An Emerging Threat*, Washington, D.C.: System Planning Corporation, 1992.

employed them on the opening night of the war in the longest bomber mission in history).[8] In 1991—almost five decades since German V-1s exploded on British soil—land-attack cruise missiles were once again employed in combat against Iraqi targets as Navy TLAMs and Air Force ALCMs struck a wide range of targets in Iraq. Navy TLAMs have also figured in subsequent punitive attacks against Iraq.

According to recent press reports, cruise missiles capable of conducting attacks against land targets are currently fielded only by the United States, some of the republics of the former Soviet Union, France, Angola, Bulgaria, Serbia, and Syria. Iran, Iraq, China, and India have well-advanced programs to develop land-attack cruise missiles, and a wide range of other nations could do the same.[9] Concern over the proliferation of these systems has increased with the advent of the satellite-based Global Positioning System (GPS), which provides latitude and longitude information on a constant basis and thus greatly simplifies guidance and targeting. For example, existing anti-ship cruise missiles could be modified to conduct strikes against land targets by adding a GPS receiver. Similar results could be obtained by adding a GPS receiver to old fighters or civil aircraft to create an unmanned "kamikaze." It should be noted, however, that many states may not wish to make weapons dependent upon a system controlled by an outside power, namely the United States.

FUTURE PROSPECTS

What are the prospects for an increasing emphasis on ballistic and cruise missiles instead of fixed-wing aircraft—the traditional means of striking into enemy territory? To gain some idea, it is necessary to explore the varied attributes of the various systems:[10]

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[8]The bomber crews referred to the conventional ALCM as the "Secret Squirrel." For data on the operation, see "The Secret Squirrels," *Air Force Magazine*, Volume 77, No. 4, April 1994, pp. 56–60.

[9]See "Cruise Missiles on the Rise," Associated Press Release, May 5, 1994.

[10]For a useful perspective, see Harvey (1992).

- **Prelaunch survivability.** Ballistic and cruise missiles, particularly mobile systems, appear to offer higher prelaunch survivability than aircraft.
- **Operating costs.** Ballistic and cruise missiles cost much less in terms of annual operating costs than manned aircraft. Launch crews can get much of their training with simulators (which are useful for some aspects of aircraft training, but not all), and only a small number of weapons need to be fired each year for reliability purposes.
- **Manned versus unmanned.** Manned aircraft place crew members' lives at risk as they penetrate enemy airspace—unmanned systems like ballistic and cruise missiles do not. This makes the latter systems particularly attractive for some missions against heavily defended targets.
- **Flexibility.** Ballistic and cruise missiles are less flexible than aircraft—they are suitable only for attack missions. In contrast, multirole aircraft can conduct both air defense and attack missions. Cruise and ballistic missiles do little to provide defense of friendly airspace except if successfully employed against adversary bases housing aircraft.
- **Payloads.** Aircraft typically can carry larger payloads than ballistic and cruise missiles.
- **Damage assessment.** Aircraft also have the potential for providing their own battle damage assessment (particularly for those systems using laser-guided bombs and video recordings).
- **Accuracy.** More accurate systems have greater lethality. Aircraft at present are much more accurate than ballistic and cruise missiles when delivering ordnance. Aircraft can achieve a circular error probable (CEP)[11] of 3 meters or so using laser-guided weapons. A fairly crude ballistic missile like the Scud has a CEP of 1,000 meters or so—the accuracy varies depending on the distance the missile flies. Early cruise missiles had CEPs mea-

[11]Circular error probable is the probability that 50 percent of the weapons employed will land within a certain distance from the target.

sured in nautical miles.[12] Cruise missiles using the commercial signal from the GPS constellation have the potential to achieve a CEP of approximately 100 meters; even greater accuracy is possible using scene-matching guidance systems or the more accurate military-coded GPS signals.[13] Ballistic missiles cannot take advantage of GPS to the same degree.[14]

- **Targets.** Ballistic and cruise missiles can at present only strike fixed targets of known location. Manned aircraft, by contrast, can strike fixed as well as mobile targets. This makes aircraft far more useful for battlefield support.

With these broad attributes in mind, ballistic missiles appear to be the weapon of choice for delivering nuclear weapons and perhaps other weapons of mass destruction.[15] Because they have short flight times, low operating costs, and are difficult to defend against, ballistic missiles are particularly attractive as a means for delivering nuclear warheads. The large land-based and sea-based nuclear-tipped ballistic missile arsenals of the United States and FSU offer mute testimony to this fact. Cruise missiles may be less attractive for this mission, since existing defenses (SAMs and aircraft) have the potential to engage and destroy these weapons. And though cruise missile guidance could be greatly simplified by using GPS receivers,

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[12]For example, a Snark test flight in December 1956 hit Brazil instead of Florida, leading some to state that the Snark had a CEP equal to its range. The errant Snark was found by a Brazilian farmer in 1982. See Werrell (1985), p. 92.

[13]CEPs of ballistic missiles and aircraft are contained in Harvey (1992), pp. 44 and 47. The potential CEPs of cruise missiles are contained in "Cruise Missiles on the Rise," Associated Press Release, May 5, 1994.

[14]See Harvey (1992), p. 71. As he notes in discussing GPS guidance for ballistic missiles:

> Even if the missile's state of motion were perfectly known prior to booster thrust cutoff, and the flight control system were able to steer the missile with sufficient precision to "zero out" velocity and orientation errors (a very big assumption), there is still the matter of inaccuracies generated during re-entry. The effects of local weather (i.e., wind and rain), and asymmetric erosion in the re-entry vehicle (RV) nose tip, can during reentry cause the warhead to drift unpredictably from its intended target. Dispersions caused by the effects of reentry are typically 50 to 100 meters for ICBM RVs, and somewhat greater for the slower RVs associated with shorter range missiles because they spend a greater amount of time within the atmosphere.

[15]For chemical and biological weapons, aircraft offer some important advantages.

it is doubtful that many nations would want their nuclear weapons delivery capability to depend upon the U.S.-controlled GPS system.

Choosing ballistic or cruise missiles as the delivery means for weapons of mass destruction, however, is unlikely to result in a large increase in the number of these weapons (though certainly an increased emphasis on defending against these systems). Only if these weapons were selected for prosecuting large-scale conventional operations would we see a major increase in the numbers deployed. We explore the potential for such an occurrence in the next section.

Fixed-Wing Versus Missiles in Conventional Operations

As discussed previously, most of the developing nations that might pose security threats to the United States have small economies. Accordingly, these nations might be concerned about the cost-effectiveness of the various systems for prosecuting conventional operations. Which is more cost-effective, missiles or aircraft? The following analysis reveals some of the complexities of the issues at stake.

For illustrative purposes, let us assume that a nation wishes to deliver about 8,000 tons of guided ordnance against a wide variety of targets. This is the total tonnage of precision-guided weapons that the United States delivered against Iraq in the Gulf War.[16] We will also assume that all the systems have the same accuracy. In reality, manned aircraft can deliver precision-guided weapons more accurately than cruise missiles[17]—and substantially more accurately than even the most advanced ballistic missiles. This assumption thus makes a "best case" for missiles.

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[16]This was computed using warhead weight as the metric. During the Gulf War, the USN, USMC, and USAF delivered 8,018 tons of precision-guided weaponry. Almost 90 percent of this was delivered by the Air Force. It included Mavericks, laser-guided bombs, TLAMs, SLAMs, Walleyes, TOWs, and Hellfire missiles. Data provided by SAF/OSX, Headquarters, United States Air Force.

[17]In the future, GPS-guided bombs and cruise missiles should feature the same degree of accuracy. However, aircraft crews will be able to employ radar updates to refine position and thus make inertially guided weapons more accurate than cruise missiles. But new terminal guidance systems could improve cruise missile accuracy as well.

How much would it cost to deliver 8,000 tons of guided weaponry with aircraft? The answer depends on assumptions about length of service and attrition rates in combat. For starting purposes, let us assume that a nation procures 50 F-15Es at $50 million apiece. Assuming a single sortie per day per aircraft, this would allow the delivery of 8,000 tons in forty days, roughly the same length as the Gulf conflict. The cost of the F-15Es would represent an initial investment of approximately $2.5 billion.

Each F-15E typically carries four 2,000-pound laser-guided bombs, each of which costs on average $50,000.[18] To deliver 8,000 such bombs would thus cost $400 million. Guided bombs are significantly cheaper than missiles because the bomb typically has no engine or fuel tanks—and crucial elements of the weapon's guidance are provided by the aircrew and subsystems of the fighter.

But there are additional factors to consider. First, aircraft can be shot down and, following the war, would have to be replaced. Aircraft attrition rates have varied widely in combat. Since 2,000 sorties would have to be flown to deliver 8,000 tons of ordnance, Desert Storm loss rates would result in the loss of one aircraft, Vietnam loss rates in 1967 would result in the loss of 10 aircraft, and Israeli air force loss rates in the 1967 and 1973 conflicts would result in the loss of 38 and 18 aircraft respectively.[19]

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[18]The costs of laser-guidance kits depend heavily on production runs. The cost of a guidance kit for a 2,000-pound bomb on an F-117, for example, runs about $100,000; the cost of a guidance kit for a 2,000-pound bomb on an F-111 runs about $10,000. The cost of the bomb itself is around $3,000. The difference is the length and scale of the production run. See *1989 Weapons File*, Munitions Systems Division, Eglin AFB, 1989, Section 5. The United States is currently developing GPS-guidance kits for general-purpose bombs, which should cost on the same order as laser-guidance kits. The advantage of the GPS-guided bombs over laser-guided bombs is that they are not vulnerable to weather conditions over the target and permit more survivable delivery techniques.

[19]In Desert Storm, the average per-sortie attrition rate for combat aircraft was 0.0004; for the Israeli air force in 1973, it was 0.009; for the Israeli air force in 1967, it was 0.019; and for the USAF in the Rolling Thunder campaign against North Vietnam in 1967, in Route Pack VI, it was 0.005. The Vietnam statistics actually overstate losses, since the only sorties counted were attack sorties (air-to-air sorties were not included). We are indebted to Dr. Wayne Thompson of the Office of Air Force History, Bolling AFB, and Lieutenant Colonel Roy Sikes, USAF, for these data. Dr. Thompson is currently completing his manuscript on USAF combat operations over North Vietnam. For additional data on Israeli loss rates, see E. Cohen (1993), p. 387.

Also, aircraft cost more than missiles to operate—crews must train regularly, while missile operations and support (O&S) costs are quite low. For example, USAF bombers on nuclear alert cost much more to operate than USAF ICBMs. A USAF F-16C costs on average about $2.8 million per year in O&S, an F-15E about $4.2 million.[20] The longer the aircraft are operated before the war, the greater the costs.

Using these factors, we laid out three alternative sets of costs for a force of 50 F-15Es delivering 8,000 tons of guided ordnance:

- Case 1 (low): Assume Desert Storm attrition rates (1 aircraft lost) and 1 year of O&S.
- Case 2 (medium): Assume 1973 Israeli Air Force attrition rates (18 aircraft lost) and 10 years of O&S.
- Case 3 (high): Assume loss of all the aircraft and 20 years of O&S.

The total costs are displayed in Figure 24.

How do these costs compare to ballistic or cruise missiles? The primary cost would be the procurement of the weapons: since the missiles are not reusable like aircraft, the attrition rate must be considered as 1.0. A range of sources indicate that each ballistic or cruise missile costs $1–2 million and can carry warheads weighing from 1,000 pounds (such as a TLAM) to 2,000 pounds.[21] To deliver 8,000 tons of ordnance, then, would consume from $8 billion to $32 billion in expenditure, depending on the assumptions made.[22]

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[20]See Stanley and Liberson (1993), p. 14.

[21]Estimates of Scud costs range from $1 million to $3 million a copy, as outlined in Harvey (1992), p. 65. More accurate ballistic missiles would cost substantially more. A TLAM costs approximately $1.5 million. For cruise missiles, one detailed RAND estimate concludes that $1 million is probably a lower-end figure for a long-range missile (with a range of 500–5,000 kilometers). See Harshberger (1991), pp. 56–67. As Harshberger notes, however, costs are likely to be higher. The United States' recent and ongoing experience with the Tri-Service Standoff Attack Missile (TSSAM) indicates that the costs can be significantly higher. Typically, initial costs are projected on a large buy. When the latter is reduced, individual unit costs increase substantially due to less-efficient production rates and the need to amortize research and development spending over a smaller buy. John Baker provides similar numbers; see his "Program Costs and Comparisons," in Betts (1981), p. 107.

[22]If one assumes $1 million per missile and a one-ton payload, 8,000 missiles would be required to deliver the 6,000 tons for an expended cost of $8 billion. If one assumes $2

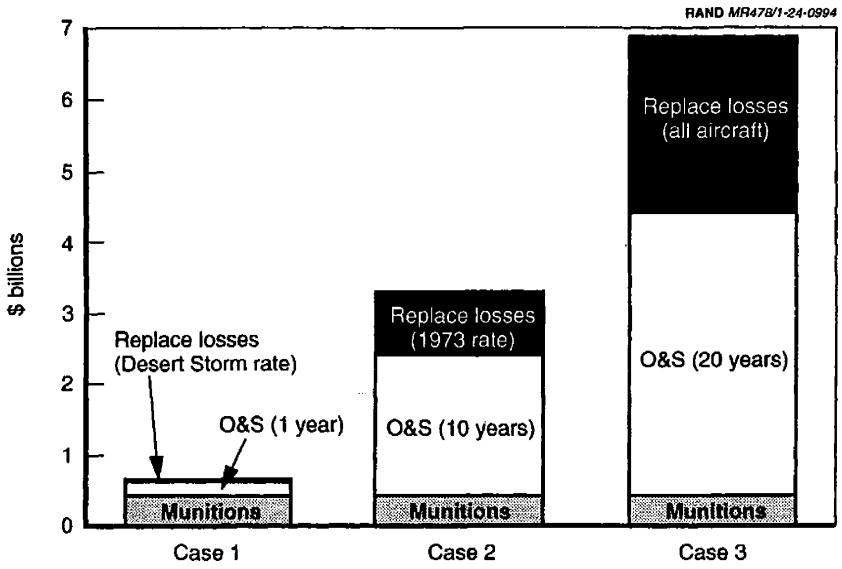

Figure 24—Potential Costs to Deliver Precision-Guided Weapons

Other costs must also be considered, such as infrastructure and operating costs, but to make the most favorable case for ballistic and cruise missiles, we will not include these costs. The resulting comparisons are shown in Figure 25.[23]

To complicate matters further, other costs must be considered that decrease the relative advantage of aircraft. Training operations would result in the loss of aircraft each year, which would need to be

million per missile and a 1,000-pound payload, 12,000 missiles would be required for an expended cost of $32 billion.

[23]Given past investment patterns, most nations have the infrastructure in place to support aircraft (e.g., runways, shelters, and hangars), but for large-scale missile operations, a substantial investment would be needed for launch and storage facilities. The Germans in World War II expended considerable effort in developing underground factories and storage facilities.

Additional sums, of course, would need to be spent on operations and support over the life of the system. For example, ballistic and cruise missiles would need to be test fired periodically to make sure that systems were performing as planned. Personnel would also need to exercise the systems to gain familiarity for wartime operations. These costs, however, will be substantially lower than those for manned aircraft.

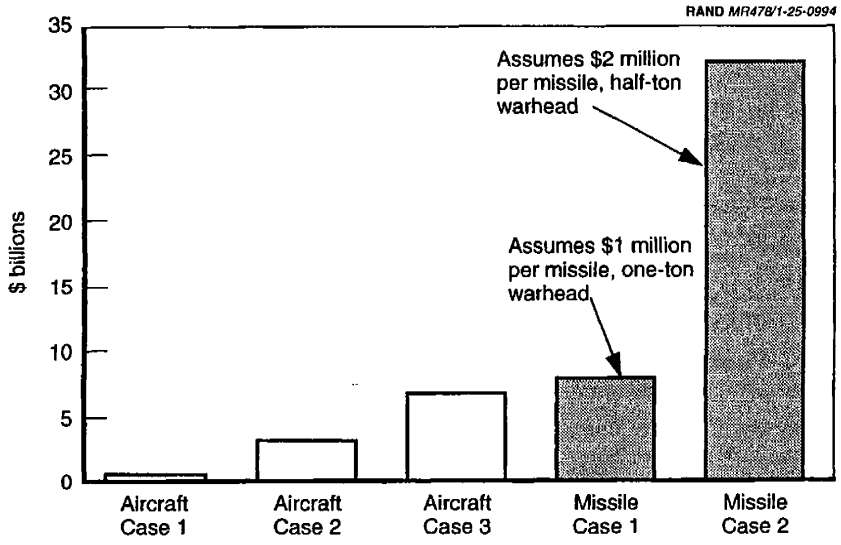

Figure 25—Comparing Manned Aircraft Costs to Ballistic/Cruise Missile Costs

replaced. Typically, the United States loses about one aircraft per year per 72-aircraft wing (numbers vary depending on aircraft type); over twenty years, then, the nation in question might need to procure an additional 14 aircraft. But even adding this amount ($700 million) would not change relative positions much. And peacetime training replacements would be needed for ballistic and cruise missiles as well, since test firing and reliability testing would require the launching of a number of weapons per year.

Conducting offensive operations with aircraft would probably require the use of force protection assets, such as air superiority fighters and aircraft designed to disrupt enemy surface-based defenses.[24]

[24]Escort requirements may have lessened with the advent of the latest generation of fighter aircraft. Modern fighters such as the F-15E, F-16, and F/A-18 typically conduct attack operations armed with both ground-attack weapons and air-to-air missiles. Accordingly, such aircraft can often function as their own escort (as was demonstrated during the Gulf conflict). The Royal Air Force employs a similar concept for suppression of enemy air defenses (SEAD) with its Tornado aircraft. Tornados can be launched carrying both the Air Launched Anti-Radiation Missile (ALARM) and

But cruise missiles would face the same problems as aircraft in penetrating defenses. In World War II, for example, the British shot down over half the V-1 cruise missiles launched against them.[25] The fielding of effective missile defenses would require a commander employing ballistic missiles to expend missiles to saturate defenses—or deliver decoys. Still, the need for support aircraft is likely to decrease the cost advantage of aircraft, but is highly dependent upon the operational situation.

But when considering the cost-effectiveness issues in the operational environment, manned aircraft appear to be much more attractive weapons systems. Aircraft can strike fixed *and* mobile targets—the latter an essential property when dealing with moving ground forces. Although it is possible that the United States might be able to field an intelligence system capable of locating a mobile target and getting this information into the guidance system of a cruise or ballistic missile, few (if any) other powers will be able to do so for many years to come.

The United States, which has had decades of experience with these systems, has adopted a mixed approach that employs ballistic and cruise missiles to complement fixed-wing aircraft. For example, in the Gulf War, F-117s bombed Baghdad at night while Navy TLAMs maintained the pressure during the day. For future U.S. punitive operations, ballistic and cruise missiles offer the signal advantage of being able to deliver firepower without placing personnel at risk. For more sustained conflicts, the United States will probably place more emphasis on manned aircraft. In short, the United States has elected to field a mix of systems to allow planners to take advantage of their unique attributes.

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ground-attack ordnance. In future, technology may permit a single aircraft, if armed appropriately, to function as a ground-attack aircraft, air superiority aircraft, and SEAD asset. And very-low-observable stealth aircraft should require no escort or support aircraft at all.

[25]The Germans launched 10,492 V-1s against the United Kingdom—1,600 from aircraft, the rest from land sites. About 2,000 crashed soon after launch. Of the remaining missiles, the British fighter and gun defenses observed 7,488 and downed 3,957 (52.8 percent). About 2,000 V-1s reached the London area, killing over 6,284 civilians and seriously injuring almost 18,000. See Werrell (1985), p. 60.

Developing nations may have a different perspective. Manned aircraft employed by the developing world have not fared well in confrontations with the airpower of the developed world. While Western air forces have planned for low loss rates, air forces in the developing world have had to consider far higher figures. For example, the Syrian air force suffered a very heavy loss rate during the 1982 Lebanon war. This perspective is bound to increase interest in other means of conducting offensive strikes.[26] Ballistic and cruise missile employment is also less sensitive to the training and experience levels required for fixed-wing forces. Once a ballistic or cruise missile is fired, it really does not matter who pressed the trigger—a Western professional or an untrained conscript. The weapon will proceed to the target area subject to the system's capabilities and reliability constraints.

IMPLICATIONS

The future is likely to see more and more nations fielding ballistic and cruise missiles. But the cost analysis indicates that these systems will be employed primarily to deliver weapons of mass destruction or to complement fixed-wing aircraft in conventional operations. For example, a limited number of missiles striking an air base could pin down aircraft and permit a more effective follow-up strike by fixed-wing aircraft. Such weapons might also prove an attractive choice for disrupting the deployment of enemy forces by striking airfields or ports in the midst of a deployment.

Attempting to do the whole job with ballistic or cruise missiles will remain an expensive proposition that may not provide the range of capabilities needed to succeed in conflict. History supplies a good example: the German Third Reich expended vast resources on its V-weapons—resources that could, as estimated after the war, have built over 24,000 fighter aircraft, which would probably have been a better investment to help defend the Reich.[27]

Another perspective might be provided by the United States. The wealthiest power in the world, the United States only plans to pro-

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[26]See the excellent analysis by Jones (1992), pp. 49–58.

[27]See Murray (1985), p. 284.

cure some 3,000–4,000 TLAMs.[28] Continuing problems with the Tri-Service Standoff Attack Missile (TSSAM), a stealthy cruise missile, have led to reductions in planned procurement quantities and increasing costs. And Army plans to procure the ATACMS continue to decline in scale. If the United States cannot procure the thousands of such systems needed to conduct conventional conflict, is it really likely that less economically advanced powers will be able to do so?

Even so, ballistic and cruise missiles cannot be ignored. And regardless of total numbers fielded, their presence will result in a variety of "opportunity costs." Nations faced with opponents wielding these systems will be forced to deal with them: defenses against cruise missiles will be needed, as will defenses against ballistic missiles. Some monies that might have been spent on offensive systems will be spent instead on defensive systems. And maintaining these defenses during conflict will cause opportunity costs as well: aircraft kept on combat air patrols to defend against cruise missiles, for example, cannot carry out offensive strikes.

Ballistic and cruise missiles *will* proliferate—the question is how great the increase will be and whether it has the potential to shift the airpower balance. Our analysis indicates that prospects for the latter are limited in terms of conventional operations. The costs and operational constraints associated with ballistic and cruise missiles indicate that their primary utility will be in complementing fixed-wing aviation and exacting opportunity costs. They do not appear to offer a means of waging sustained conventional conflict, for reasons of both cost and their inability to deal with mobile targets. Nonetheless, defenses against these systems will remain a high priority for the United States and other nations threatened by them.

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[28]See Harshberger (1991), p. 3.

Chapter Seven

CONCLUSIONS

The inventory data reveal that most of the world's powers—and the United States in particular—have spent more resources on fixed-wing aviation than on other forms of airpower. Fixed-wing aviation will also remain the combat backbone of U.S. airpower forces for many years to come and thus formed the primary focus of this analysis. But planners and strategists must be careful to consider other forms of airpower when looking at the future balance, and we would like to offer the following observations.

- Helicopters can conduct an increasingly important set of military operations—with one crucial exception. They are poorly suited to dispute control of the air and would not fare well when confronted with capable fixed-wing combat forces. An adversary that increased investment in rotary-winged systems thus would not improve its relative position to U.S. airpower.
- SAMs can dispute control of the air and so can play an important role in the airpower balance. The data to date, however, indicate that few nations have placed a heavy emphasis on SAMs to defend their airspace. But the potential of these systems means that they merit specific attention. The ongoing proliferation of man-portable SAMs combined with anti-aircraft gun defenses have apparently reduced the capability of fixed-wing aircraft to operate at low altitudes over defended areas with acceptable levels of attrition. Suppression prospects against these systems appear poor. U.S. strategy relies heavily on employing fixed-wing aircraft to penetrate and exploit enemy airspace in conflict. Accordingly, the potential for nations to deny employment of the

medium and high altitudes by emphasizing longer-range SAMs bears careful watching and the adoption of appropriate counters.

- Our analysis illustrates that ballistic and cruise missiles appear particularly suitable for delivery of weapons of mass destruction and as terror weapons. For developing nations, they offer a means to strike deep into an adversary's territory with greater certainty than strikes conducted by fixed-wing aviation. Cost and operational constraints, however, indicate that in sustained conventional operations, they are best suited to complement fixed-wing airpower and to exact opportunity costs. In particular, these systems have only a poor ability to deal with mobile targets, such as maneuvering ground forces. Ballistic and cruise missiles can complement fixed-wing aircraft, but not replace them.

When examining the fixed-wing balance, the United States—and its traditional allies—have long placed heavy emphasis on fixed-wing airpower and have earnestly sought to increase the potential of these systems and understand their most effective employment. In the 1980s, the United States and, to a lesser extent, its Western allies made a massive investment in airpower. That investment has placed the United States in a commanding position in terms of the global balance of airpower. The United States appears capable of gaining and exploiting control of the air in a theater conflict for the foreseeable future.

The combination of a strong economy and national wealth has placed the United States in an extremely advantageous position in terms of the airpower balance. Relative to other nations and regional powers, the fixed-wing airpower weapon that has emerged at the close of the Cold War can be maintained and improved by the United States at a comparatively moderate cost, due to the large size of the U.S. economy and the modern force structure currently in being. The end result is that a U.S. air dominant strategy is one that will prove extremely difficult to deal with "in kind." Simply put, it is a strategy that favors the richer powers.

Attempts to shift the airpower balance would require massive investment by regional powers. This would require corresponding massive growth in regional economies (something that cannot be as-

sured and, in any case, would take many years to achieve) or a substantial shifting of the effort of national economies. Diverting an increasing proportion of national treasure to the military may subvert efforts to develop more robust economies. In addition, shifts in spending patterns could upset the political balance of interservice power in many developing states (where ground forces are often the dominant institution). Given the battles among U.S. Services over any changes in their shares of the defense budget, regional airpower forces would seem to have little chance for success in any such internal imbroglios. These factors, combined with the poor position of regional airpower forces in terms of modernization and size, suggest that most other airpower forces across the world will shrink in size.

The preceding has painted a picture of overwhelming U.S. dominance in terms of the airpower balance—both at the close of the Cold War and for the foreseeable future. To maintain this powerful air weapon will require continued investment to ensure that potential opponents cannot inflict significant attrition, either through modernized fixed-wing air arms or SAM-heavy defenses. Most importantly, we must consider the U.S. position in the airpower balance within the context of U.S. national strategy. Three key related issues are: (1) the need to maintain forces capable of dealing with two concurrent major regional conflicts; (2) the requirement to fight expeditionary campaigns; and (3) the employment of airpower forces to achieve multiple operational objectives.

TWO CONCURRENT CONFLICTS

Current U.S. national military strategy calls for the capability to deal with two concurrent major regional conflicts (that is, conflicts that may erupt sequentially but must at times be prosecuted simultaneously).[1] Whether or not one believes there is a high probability that the United States will ever have to prosecute two concurrent conflicts, sizing its forces to meet more modest criteria could engender a range of risks. In the event of a major conflict in one region, such a posture could open up opportunities for an aggressor in another region. It would leave the United States vulnerable in the event a larger

[1]See Bowie et al. (1993), pp. 5–6.

threat arose. It would also inhibit decisionmakers from deploying a force to a theater if they were concerned that another conflict might erupt.

A larger force structure provides flexibility and some margin for responding to the unexpected—both valuable qualities when dealing with something as inherently uncertain as military operations ten or twenty years from now. Sizing forces for two conflicts need not cost twice as much as sizing for one, since many key elements of the military infrastructure do not need to be expanded to the same level. But the two-conflict requirement does require the United States to maintain a larger force structure overall—and it heightens the importance of dominance in the airpower balance.

EXPEDITIONARY CAMPAIGNS

U.S. planning is focused on fighting expeditionary wars far from its shores. These are among the most challenging military operations to conduct. Vast amounts of equipment must be deployed thousands of miles; personnel and equipment must operate in an often unfamiliar environment at short notice. The need to deploy forces over great distances means that U.S. forces must build up over time. This will limit the size of the U.S. fighting force in the crucial early phases of an engagement, and the overall U.S. theater force size will be only a portion of the total force.

In contrast, enemies engaged will typically be close to their home turf and can thus draw on their total force. In the initial stages of a fast-breaking conflict, a small adversary airpower force could well outnumber the initial complement of deploying U.S. forces. Adversary forces could use this advantage to disrupt the exacting process of deployment, reducing U.S. combat capabilities while seeking to achieve various objectives. The longer that U.S. theater force levels can be minimized, the greater the chances for an adversary to succeed in aggression.

The potential for attack could force U.S. forces to deploy to rear-area bases and keep carrier aviation at greater distances from the scene of combat, which in turn would reduce sortie rates and overall force effectiveness. Moreover, losses incurred in the initial phases of com-

bat could exert a powerful effect on U.S. public opinion and raise questions as to the wisdom of continuing the conflict.

A relevant illustration is provided by the Falklands war, where British airpower forces on the scene were outnumbered by Argentine airpower forces.[2] As the British battle group commander noted in his recent memoirs, the loss of one of his two carriers would probably have forced the task force to withdraw due to the inability to provide even a minimal air defense for operations.[3] The British also had to be concerned about the political impact of combat losses. Had the Argentines possessed additional Exocets (which proved highly effective) or had more of their bombs fused properly, the resulting British losses might have forced a withdrawal and the pursuit of negotiations.

AIRPOWER'S MULTIPLE OPERATIONAL OBJECTIVES IN U.S. MILITARY STRATEGY

Comparisons of the airpower balance cannot be made in isolation. The United States relies on its airpower to achieve multiple and often concurrent operational objectives: to gain control of the air and then exploit that medium to attack enemy surface forces and warfighting infrastructure. *It is not sufficient for the United States simply to possess sufficient airpower to defeat enemy airpower.* That is a crucial job, but not the only one. In contrast, if an opponent were able to successfully challenge U.S. forces for control of the air, his prospects for success would improve markedly. An adversary, for example, could focus his limited airpower resources on the air defense role.

In contrast, U.S. airpower must be capable of a much wider range of missions. These forces must not only eliminate the adversary's airpower forces quickly and efficiently, but must concurrently stop the land offensive as quickly as possible, to minimize loss of terrain, and also conduct strikes against the enemy's warfighting infrastructure.

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[2]The distance of the Falkland Islands from the Argentine mainland, however, served to limit the number of sorties Argentina could mount and the amount of time Argentine fighters could fly over the islands.

[3]See Woodward (1992), p. 5.

ASYMMETRIC STRATEGIES

This analysis has illustrated quite starkly that attempts to challenge the United States in terms of airpower will be extremely difficult. In some ways, the United States employs what might be termed an "asymmetric" strategy, one that pits its strength—land-based and sea-based airpower—against most adversaries' strength—land power. But the small likelihood that potential adversaries can field an in-kind challenge means that the United States must keep a careful eye on their prospects for developing their own "asymmetric" strategies.

The case of the Swedish air force is useful for understanding what might be termed an "asymmetric" strategy. To deter a Soviet attack, the air force was envisioned to play a critical role in Sweden's defense, particularly in the crucial initial phases of conflict. Its key roles were to protect Swedish airspace and attack amphibious and airborne assaults.[4] Concerns about base vulnerability to attack led the air force to adopt a dispersed basing scheme: a variety of dispersed operating surfaces were prepared (some using elements of the national road network); mobile maintenance, refueling, and rearming facilities were created; and aircraft were specifically designed to operate in a dispersed fashion. If the potential for conflict were to arise, then the air force, which depends heavily upon mobilization to bring up its fighting strength, would disperse and prepare for operations.

In 1986, as Gordon McCormick relates, the Swedish government announced that

> Soviet intelligence personnel (GRU), posing as Polish art dealers, had called at the homes of some 120 Swedish pilots for the apparent purpose of determining their identities, family situations, and routines. According to Swedish authorities, the larger objective of these visits was to support a Soviet plan to decapitate the [air force] in the event of war. Swedish pilots would be gunned down in their homes before they were able to answer their mobilization call.[5]

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[4]See Bitzinger (1991), p. v.

[5]McCormick (1990), p. 24.

The Soviet Union certainly had sufficient airpower to engage the Swedish air force in the air. But instead, it elected to engage personnel in their beds. This is what could be termed an "asymmetric" strategy.

The United States cannot assume that potential enemies will remain still. After each decisive victory, the losing side has tended to learn more than the winning side. The Gulf War was played out on a global stage and has spawned a growth industry in lessons learned. We can be confident that the various powers are studying that war to assess U.S. strengths and weaknesses.

Clearly, airpower remains a strength that the United States must strive to maintain and improve—it underpins U.S. military strategy. But asymmetric strategies could be employed to try and negate this strength. To lay out just a few possible responses, such strategies could include:

- Developing weapons of mass destruction to deter U.S. intervention;
- Developing a more lethal surface-based defense network;
- Implementing massive dispersal of strategic and military targets to deny airpower useful targets;
- Colocating key military targets with civilian structures to inhibit U.S. strikes;
- Employing special forces in attacks against key facilities, such as air bases and ports;
- Burying facilities deep underground (as North Korea has done).

Such strategies will not be easy to implement or prosecute in the face of the current and future U.S. overwhelming advantage in airpower. Only the future can tell us which strategies will be employed and whether they will be effective. It is clear that the United States must maintain its powerful air weapon in order to support its national security. And it is equally clear that the United States must also keep a watchful eye on the activities of potential foes (and develop counters where appropriate) as it enters this increasingly uncertain era.

Appendix

FIGHTER MODERNIZATION METHODOLOGY

When calculating the potential costs of airpower modernization in the various regions of the world, we assumed for analytic purposes that nations would try to replace all "old" and "useful" aircraft with front-line fighters.[1] We did not examine the option of upgrading existing aircraft, because of the uncertainties involved in the costs, effectiveness, and long-term viability of such a course (although our analysis may afford some perspective on the subject). We then deduced the likelihood of modernization by examining the burden each region's required annual aircraft procurement costs would place on its economy. Results from this analysis are provided below.

Estimating fighter modernization requirements means estimating the cost of a new front-line fighter. We employed two approaches. The first assumed that all regions will purchase new "high-end" front-line fighters (an F-15, Tornado, or Rafale class aircraft) costing $50 million each. This approach has the advantage of illustrating the relative predicaments of all nations according to the same underlying assumptions. Of course, it is unrealistic to believe that much of the developing world would spend quite so much for each new front-line fighter, and many developing countries could opt instead for more affordable fighters such as F-16s. As a consequence, we explored several cases in which the industrial regions purchase $50-million front-line fighters and most of the developing world purchases $25-million fighters.

[1]This actually understates requirements, since some front-line fighters will reach the end of their fatigue lives in the coming decade and need replacement.

In order to make assessments of the affordability of fighter modernization, we examined three cases. In all of these, the nations of the developed world replace their old and useful fighters on a one-for-one basis using $50-million fighters. The variables for the developing world include:

- Replacing their old and useful fighters on a one-for-one basis using a $50-million fighter;
- Replacing their old and useful fighters on a one-for-one basis using a $25-million fighter; and
- Replacing their old and useful fighters on a one-for-two basis using a $25-million fighter.

We then analyzed three related sets of statistics:

- The percentage of expected future GNP that nations attempting to modernize would spend on fighter modernization. This set of statistics provides insights into the burden that fighter modernization will place on the overall economy of each region.
- The percentage of expected central government expenditures to be spent on fighter modernization. These statistics yield insights into how much fighter modernization might affect the future discretionary public policy funds available to each region.
- The percentage of expected military expenditures to be spent on fighter modernization.

We employed these statistics to examine the top 50 defense-spending nations, which are listed in Figure A.1 and account for virtually all of the world's defense spending.

Each set of statistics was compared to the weighted world average of that statistic in order to infer the difficulty of fighter modernization of each nation relative to the others. The results of these calculations are summarized in Figures A.2 and A.3. The following discussion provides some additional insights and should be read in conjunction with the summary provided in Figures A.2 and A.3.

Figure A.1—The Top 50 Defense-Spending Nations

United States

The burden of fighter modernization for the United States should be comparatively low. The values of U.S. fighter modernization as a percentage of GNP, federal budget, and total defense spending are all well below the weighted world average of each, indicating that the United States will face less difficulty in modernizing its air forces than most of the rest of the world.

Western Europe

Western Europe should also face a relatively light fighter modernization burden, as this region's values for the three statistics examined are also below or close to the weighted world average of each. How-

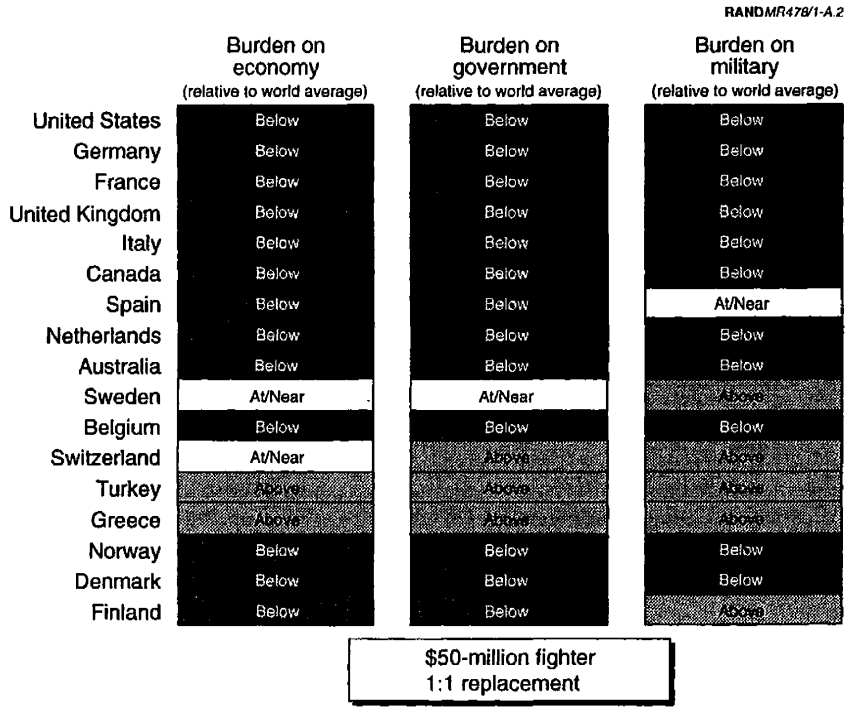

Figure A.2—Fighter Modernization Burden on the United States and Western Europe

ever, several interesting inferences can be drawn here. Although the required annual fighter procurement expenditures of Western Europe and Canada as a percentage of expected GNP are roughly the same as those of the United States, they are much *lower* as a percentage of expected central government expenditures and much *higher* as a percentage of expected military expenditures. In essence, the West Europeans have vast discretionary central government resources but do not spend a correspondingly large amount on defense.

Some nations that appear to face a relatively high fighter modernization burden are Turkey, Greece, and Sweden.

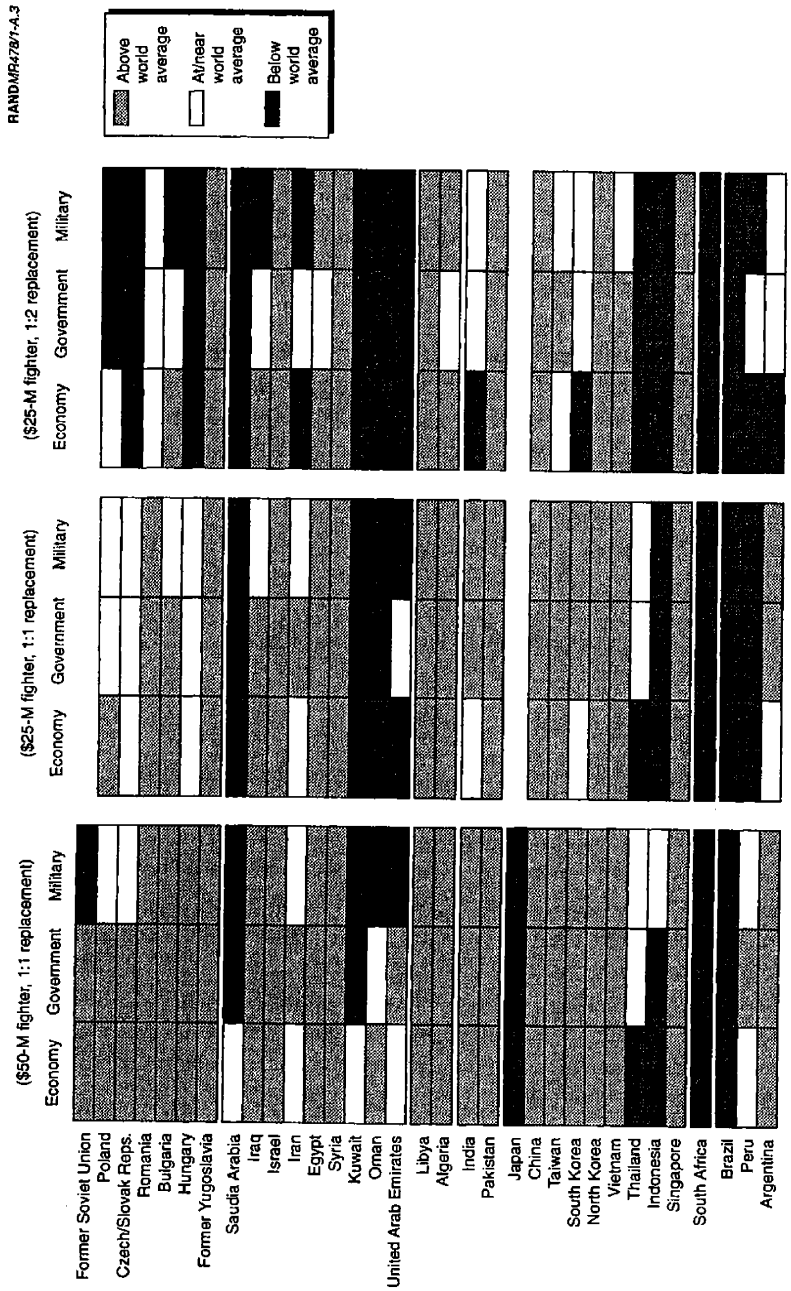

Figure A.3—Fighter Modernization Burden on the Rest of the Top 50 Defense-Spending Nations

Former Soviet Union and Eastern Europe

The recent political and economic turmoil in the former Soviet Union and the newly emerging democracies in Eastern Europe render difficult any estimations about future fighter modernization. Using historical data to estimate future developments in the former Warsaw Pact countries is at most a second-best solution. In the absence of a better method, however, we report the results of this methodology and advise the reader to apply them with caution.

The annual shares of expected GNP, central government expenditures, and military expenditures that are required for fighter modernization are high for all the nations of this region—higher than the world averages—except in the case of the former Soviet Union, for which fighter modernization should be hard on its economy and government but relatively easy on its military. Fighter modernization would be a considerable burden to the economies of the former Warsaw Pact nations. But since the former Soviet Union historically spent a large share of its GNP and central government funds on the military, future fighter modernization might not be more painful than similar past modernization campaigns were.

Pacific and South Asia

The Pacific and South Asia regions had impressive economic growth in the period under examination. During this time, Japan emerged as a global economic superpower, while South Korea, Taiwan, and Indonesia proved to be worthy competitors in international technology markets. Considering the large sums of wealth produced in this region, it comes as no surprise that fighter modernization goals appear affordable to some of its nations, such as Japan, Thailand, and Indonesia. On the other hand, several other nations, namely Taiwan, North Korea, South Korea, Singapore, and Vietnam, should have difficulty relieving their fighter modernization burden even by reducing force structure and purchasing cheaper fighters.

It must be noted that these regions have spent relatively little on defense, compared to the West. Japan, for example, has devoted only a small amount of its resources to its military. As a result of the current low level of military expenditures (as a percentage of GNP and central government expenditures), fighter modernization appears more

difficult. But the large sums of wealth in the region imply that its governments have the opportunity to decide to increase defense expenditures to render air force modernization feasible. It is only a matter of marshaling sufficient political will to do so.

India and Pakistan also face considerable difficulty in fighter modernization, although India's prospects are relatively better than Pakistan's if India opts for fewer or cheaper fighters.

China

China faces a daunting fighter modernization challenge. During the last several decades, China procured a large number of old fighters (typically, indigenously built versions of Soviet fighters). Our analysis strongly suggests that it is very unlikely that the Chinese could modernize all of their old and useful fighters, even if they were to replace them at a rate of two old and less-useful fighters for one, relatively inexpensive, new front-line fighter. The Chinese simply have too many old and less-useful fighters for modernization of their existing fighter force to be feasible.

The Middle East/Southwest Asia

The required annual fighter procurement resources as percentage of expected GNP, central government expenditures, and military expenditures are all high for Iraq, Israel, Egypt, and Syria, assuming that these nations will attempt to replace old and less-useful fighters with front-line fighters on a 1:1 ratio. Of these countries, reducing force structure and fighter cost helps only Iraq in relieving its modernization burden.

Saudi Arabia and its neighbors Oman and the United Arab Emirates are surprisingly well-situated to undertake fighter modernization, even without sacrificing force structure size and the quality of new fighters. (Inferences about Kuwait are not recommended, since our data preceded the Gulf War, an event that altered Kuwait's economic situation drastically.)

It must be noted, though, that Middle Eastern countries have historically spent high amounts of their GNP and central government budgets on the military, which tends to hide the effects of fighter mod-

ernization. Even under a 1:2 replacement rate, the burden of air force modernization on the overall economy and available central government funds of the region is still very high, indicating that while fighter modernization may be possible under the 1:2 replacement scenario, given the historically high importance of military spending in this region, it would exact a substantial economic toll overall.

North Africa

Libya and Algeria would face serious and perhaps insurmountable difficulties in modernizing their fighters by purchasing new $50-million front-line fighters and replacing on a 1:1 ratio. Even shifting towards $25-million front-line fighters on a 1:2 replacement ratio results in a severe strain on national resources.

South Africa

South Africa's fighter modernization burden on its economy, government, and military are all under the world average. Consequently, fighter modernization is a realistic goal for South Africa.

Latin America

Brazil, Peru, and Argentina have few fighters in relation to their economies. Brazil and Peru thus have relatively light modernization prospects, especially if they choose to buy $25-million fighters. Argentina's situation is less positive, and it would have to sacrifice quality and force structure in order to make fighter modernization a realistic prospect.

Summary Points

Most countries of the Western world have a relatively light fighter modernization burden; conversely, most non-Western nations have a relatively heavy fighter modernization burden. The preceding logic indicates that one way nations may relieve their modernization burden is by switching to cheaper fighters and reducing force structure. Of course, there are many possible pathways to affordability, such as

deliberately choking the overall economy in favor of the military or diverting funds from other services toward the air force. Another possibility is the hope that economic growth might be sufficient to render modernization affordable. Therefore, at this point, we ask the question, "Is it reasonable to expect that economic growth will reduce the burden of fighter modernization on nations to the point that it becomes affordable?"

Figure A.4 shows the average annual real GNP growth rates of the top 50 defense-spending nations during the period under review, 1979–1989. The world average was 2.6 percent annual real GNP growth, which was almost precisely the growth rate experienced by the United States during this period, demonstrating the extent to which the United States sets the pace of world economic growth. Some nations in the Pacific region performed extraordinarily well. China's economic revolution of the 1980s resulted in an astounding 8.9 percent growth rate. Taiwan, Singapore, Thailand, and South Korea also performed remarkably well, with growth rates of approximately 7–8 percent. The Middle East had disappointing economic growth, presumably because of the fall in oil prices in the 1980s. The national incomes of Libya, Iraq, Saudi Arabia, the United Arab Emirates, and Kuwait actually shrank during this period.

Figure A.4 suggests that an annual growth rate of 8 or 9 percent would be extraordinary for any nation. Let us now explore what type of annual growth rates are required for nations that have heavy modernization burdens to bring their burden down to the world average in a period of ten years. The results are illustrated in Figure A.5.

In order to "grow their way into affordability," many of the nations that now have heavy fighter modernization burdens would need to grow at unrealistically high rates. For example, for Libya to bring its actual fighter modernization burden on its economy down to the world average, it would need to grow at about 28 percent per year, clearly an unattainable rate. Meeting the world average burden of modernization on Libya's government and military would be nominally easier, requiring "only" 20 percent and 15 percent annual GNP growth rates, still substantially difficult. Some nations, however, might realistically expect that economic growth would allow fighter modernization to become an affordable goal. The growth rates required for Taiwan and South Korea are not at all inconsistent with

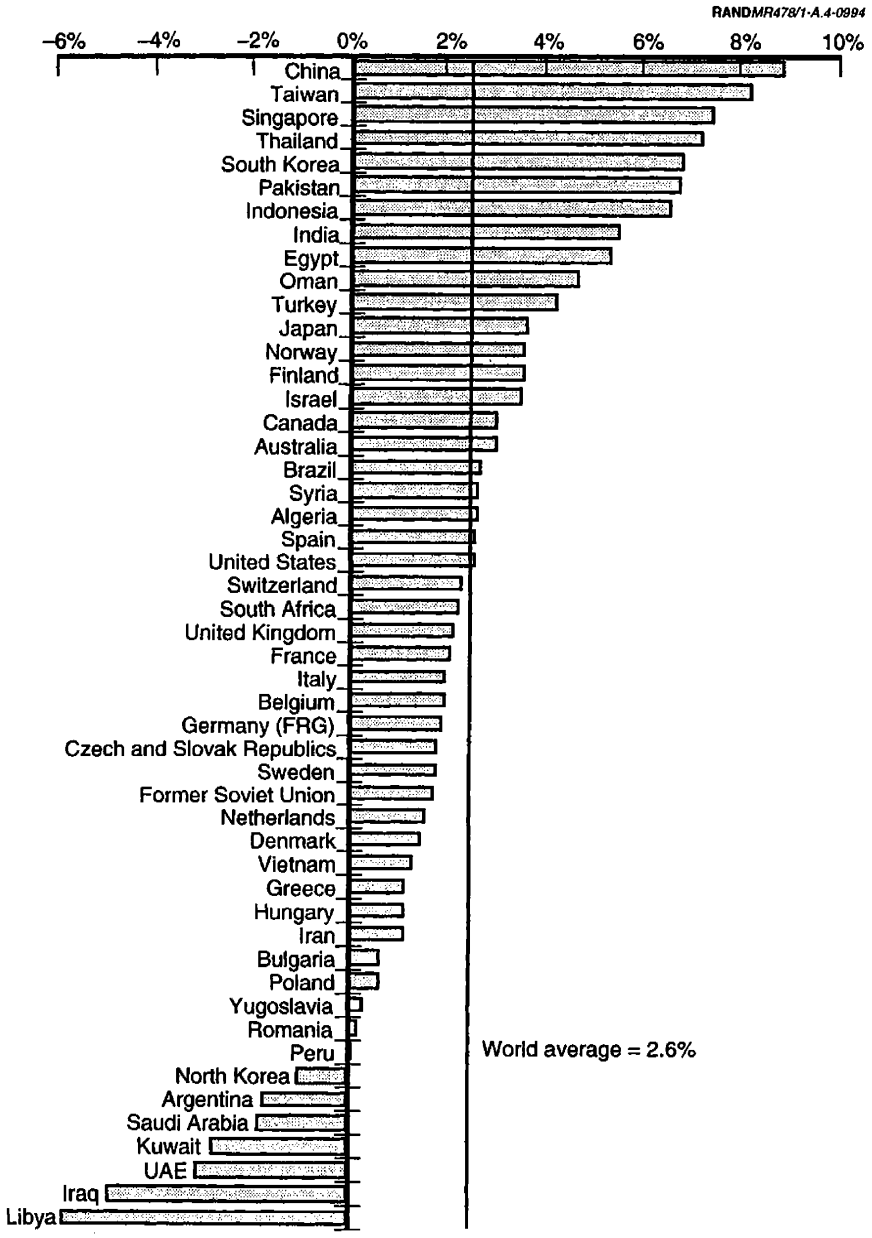

Figure A.4—Average Annual GNP Growth Rates (1979–1989) for the Top 50 Defense-Spending Nations

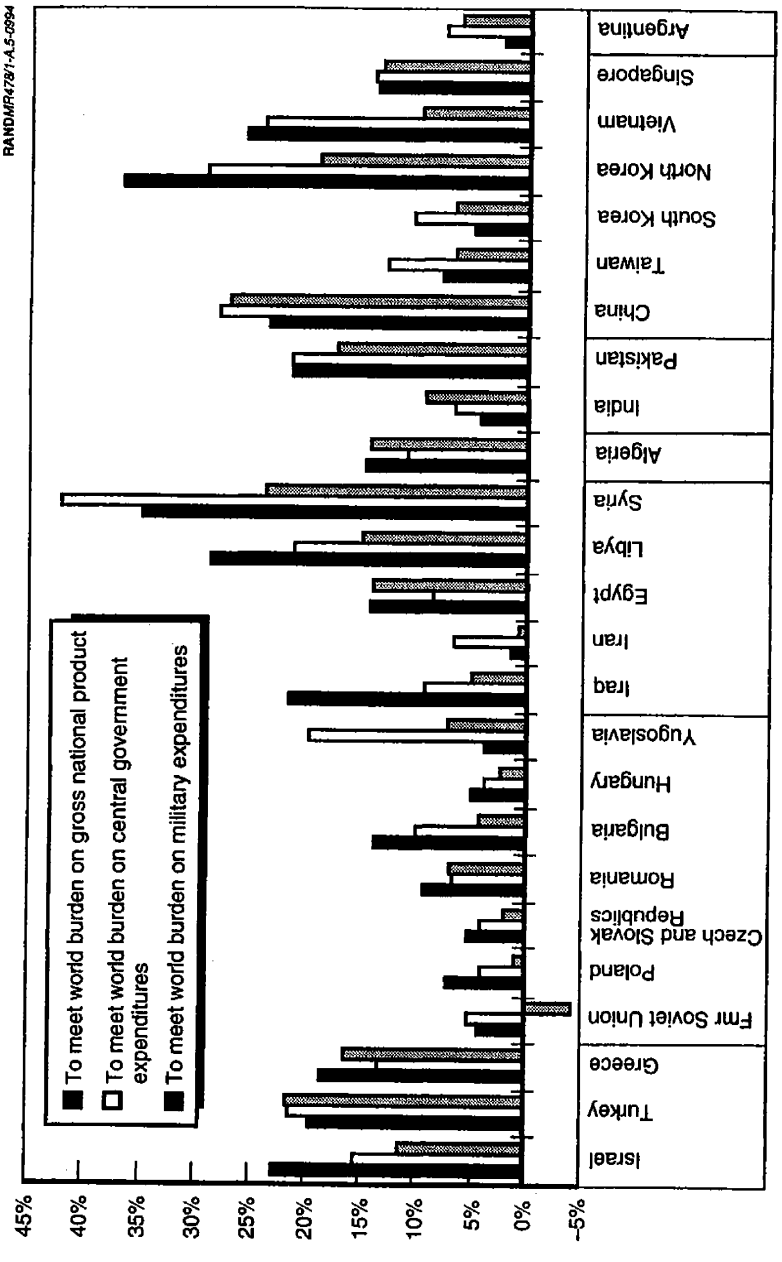

Figure A.5—GNP Growth Rates Required over Ten Years to Bring Actual Burden Down to the World Average Burden

previous economic performance. Iran, India, and Argentina also have low growth-rate requirements, although their prior economic performance indicates that achieving such rates would be a challenge.[2]

[2]We are reluctant to make claims about the former Warsaw Pact nations because of the uncertainty of the available GNP and military expenditure data.

SELECTED BIBLIOGRAPHY

Ackerman, Julia A., and Michael Dunn, "Chinese Airpower Revs Up," *Air Force Magazine*, July 1993.

"The Air Force Today and Tomorrow," interview with Colonel General Yevgeniy I. Shaposhnikov, *Aviatsiia i kosmonavtika*, No. 8, August 1990.

Arms Control and Disarmament Agency, *World Military Expenditures and Arms Transfers 1990 (WMEAT)*, Washington, D.C.: U.S. Government Printing Office, 1990.

Aspin, Les, *Report on the Bottom-Up Review*, Washington, D.C.: Department of Defense, October 1993.

Aviation Advisory Services Limited, *International Air Forces & Military Aircraft Directory*, 1991.

Aviation Week and Space Technology, selected issues.

Barrie, Douglas, and Alexander Velovich, "Fighting Over the Scraps," *Flight International*, June 1–7, 1994.

Betts, Richard K. (ed.), *Cruise Missiles: Technology, Strategy, Politics*, Washington, D.C.: The Brookings Institution, 1981.

Bitzinger, Richard, *Facing the Future: The Swedish Air Force, 1990–2005*, Santa Monica, CA: RAND, R-4007-RC, 1991.

Bowie, Christopher, Fred Frostic, Kevin Lewis, John Lund, David Ochmanek, and Philip Propper, *The New Calculus: Analyzing Air-*

power's Changing Role in Joint Theater Campaigns, Santa Monica, CA: RAND, MR-149-AF, 1993.

Bowie, Christopher, Mark Lorell, and John Lund, *Trends in NATO Central Region Tactical Fighter Inventories 1950–2005*, Santa Monica, CA: RAND, N-3053-AF, 1990.

Chant, Christopher, *World Encyclopedia of Modern Air Weapons*, Wellingsborough: Patrick Stevens Limited Publishing, 1988.

"China's Military Aircraft Inventory," *Flight International*, November 25, 1992.

Cohen, Eliot A., "The Mystique of U.S. Air Power," *Foreign Affairs*, Vol. 73, No. 1, January/February 1994.

Cohen, Elizier, *Israel's Best Defense: The First Full Story of the Israeli Air Force*, New York: Orion Books, 1993.

Cohen, Jon, "China's Combat Aircraft Domestic and Export Production Schedules for Firm Orders 1992–2000," *Global Arms Market*, Table 4.12, Institute for Defense and Disarmament Studies, 1994.

Davis, Paul K. (ed.), *New Challenges for Defense Planning: Rethinking How Much Is Enough*, Santa Monica, CA: RAND, MR-400-RC, 1994.

Defense and Foreign Affairs Handbook, Washington, D.C.: Perth, 1990–1991.

Defense and Foreign Affairs Strategic Policy, Washington, D.C.: Copley & Associates, December 31, 1992.

Department of Defense, *Conduct of the Persian Gulf War*, Washington, D.C., April 1992.

"Flying in the Face of Adversity," interview with Petr Butowski, *Jane's Defense Weekly*, April 17, 1993.

Frostic, Fred, *Air Campaign Against the Iraqi Army in the Kuwaiti Theater of Operations*, Santa Monica, CA: RAND, MR-357-AF, 1994.

Frostic, Fred, and Christopher J. Bowie, "Conventional Campaign Analysis of Major Regional Conflicts," in Davis (1994).

Garrity, Patrick J., *Why the Gulf War Still Matters: Foreign Perspectives on the War and the Future of International Security,* Los Alamos: Center for National Security Studies, Los Alamos National Laboratory, Report No. 16, July 1993.

Harshberger, Edward R., *Long Range Conventional Missiles: Issues for Near-Term Development,* Santa Monica, CA: RAND, N-3328-RGSD, 1991.

Harvey, John R., "Regional Ballistic Missiles and Advanced Strike Aircraft: Comparing Military Effectiveness," *International Security,* Vol. 17, No. 2, Fall 1992.

Hosmer, Stephen T., "Weapons of Mass Destruction and the Persian Gulf War," *Project AIR FORCE Annual Report Fiscal Year 1993,* Santa Monica, CA: RAND, AR-3900-AF, 1994, pp. 9–12.

International Defense Review, selected issues.

International Institute for Strategic Studies, *The Military Balance,* London: IISS, selected issues.

International Monetary Fund, *International Financial Statistics,* Washington, D.C.: IMF, 1992.

Irving, David, *The Mare's Nest,* London: William Kimber and Co., 1964.

Jane's Defence Weekly, selected issues.

Jane's Information Group, *DMS Market Intelligence Reports, Foreign Military Markets NATO & Europe,* London, 1989.

———, *Jane's All the World's Aircraft,* London, 1991–1992.

———, *Jane's Land-Based Air Defence 1992–93,* London, 1992–1993.

Jones, Greg, *The Iraqi Ballistic Missile Program: The Gulf War and the Future of the Missile Threat,* Marina del Rey, CA: American Institute for Strategic Cooperation, 1992.

Kaminer, R. A., "Israel Reveals Unprecedented Level of Defense-Budget Details," *International Defense Review,* January 1994.

Keaney, Thomas A., and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report*, Washington, D.C.: U.S. Government Printing Office, 1993.

Lambeth, Benjamin, *Desert Storm and Its Meaning: The View From Moscow*, Santa Monica, CA: RAND, R-4164-AF, 1992.

———, "Russian Airpower at the Crossroads," *Project AIR FORCE Annual Report Fiscal Year 1993*, Santa Monica, CA: RAND, AR-3900-AF, 1994, pp. 50–53.

Large, J. P., A. A. Barbour, and G. F. Mills, *Procedures for Estimating Life-Cycle Costs of Electronic Combat Equipment*, Santa Monica, CA: RAND, R-3530-AF, 1988.

Levin, Mikhail, "That Same MiG," *Krylia Rodiny*, No. 3, 1992.

Lewis, Kevin, *Planning Future U.S. Fighter Forces*, Santa Monica, CA: RAND, MR-285-AF, 1993.

———, *The U.S. Air Force Budget and Posture over Time*, Santa Monica, CA: RAND, R-3807-AF, 1990.

Lorell, Mark, *The Future of Allied Tactical Fighter Forces in NATO's Central Region*, Santa Monica, CA: RAND, R-4144-AF, 1992.

McCormick, Gordon, *Stranger Than Fiction: Soviet Submarine Operations in Swedish Waters*, Santa Monica, CA: RAND, R-3776-AF, 1990.

Military Aviation News, selected issues.

Millot, Dean, Roger Molander, and Peter Wilson, *"The Day After..." Study: Nuclear Proliferation in the Post–Cold War World*, 3 vols., Santa Monica, CA: RAND, MR-266-AF, 1993.

Ministry of Defence, *RAF Air Power Doctrine (AP 3000)*, London: Ministry of Defence, 1992.

Missile Forecast, selected issues.

Missile Monitor, selected issues.

Munitions Systems Division, *1989 Weapons File*, Eglin AFB: United States Air Force, 1989.

Murray, Williamson, *Luftwaffe*, Baltimore: Nautical and Aviation Publishing Co., 1985.

Nagler, Robert, *Ballistic Missile Proliferation: An Emerging Threat*, Washington, D.C.: System Planning Corporation, 1992.

Nation, Joseph E., *German, British, and French Military Requirements and Resources to the Year 2005*, Santa Monica, CA: RAND, N-2982-RGSD, 1992.

Naval Institute Press, *Combat Fleets of the World, 1988/89, Their Ships, Aircraft, and Armament.*

Northrop Corporation (Advanced Technology and Design Center), *Air-To-Surface Munitions Handbook*, revision, 1992.

Office of Air Force History, *Encyclopedia of U.S. Air Force Aircraft and Missile Systems*, Washington, D.C., 1978.

Oxford University Press, *SIPRI Yearbook, 1992—World Armaments and Disarmament*, Oxford, 1992.

"Russia to Scrap 2,000 Aircraft," *Flight International*, March 31–April 6, 1993.

Shaver, Russell, Edward R. Harshberger, and Natalie W. Crawford, *Modernizing Airpower Projection Capabilities: Future Needs and Options*, Santa Monica, CA.: RAND, IP-126, 1993.

Simon, Yolande, *Prospects for the French Fighter Industry in a Post–Cold War Environment: Is the Future More Than a Mirage?* Santa Monica, CA: RAND, RGSD-106, 1993.

Spick, Michael, *Jet Fighter Performance: Korea to Vietnam*, London: Ian Alled Ltd., 1986.

Spellman, A., "Avionics Programs at Core of Latest Israeli Outreach to India," *Armed Forces Journal International*, November 1992.

Stanley, William, and Gary Liberson, *Measuring Effects of Payload and Radius Differences of Fighter Aircraft*, Santa Monica, CA: RAND, DB-102-AF, 1993.

Stein, David, *The Development of NATO Tactical Air Doctrine, 1970–1985*, Santa Monica, CA: RAND, R-3385-AF, 1987.

Terekhov, Vyacheslav, and Viktor Akimov, "Interview with Kokoshin," *Interfax*, December 3, 1992.

Tirpak, John, "The Secret Squirrels," *Air Force Magazine*, Vol. 77, No. 4, April 1994.

United States Air Force (SAF/OSX), *B-2 Survivability Against Air Defense Systems*, Washington, D.C.: Headquarters, United States Air Force, March 1990a.

United States Air Force, *Basic Aerospace Doctrine of the United States Air Force*, vol. 1, Headquarters, United States Air Force, 1990b.

"U.S., French Fighter Sales to Taiwan Nudge Mainland China Closer to Russia," *Armed Forces Journal International*, January 16, 1993.

Vladykin, O., "The Military Budget: Priority for Social Needs," interview with Lieutenant General V. Vorobyev, *Krasnaia zvezda*, February 4, 1992.

Werrell, Kenneth P., *Archie, Flak, AAA, and SAM, A Short Operational History of Ground-Based Air Defense*, Maxwell AFB, AL: Air University Press, 1988.

———, *The Evolution of the Cruise Missile*, Maxwell AFB, AL: Air University Press, 1985.

Wollen, M.S.D., "MiG-21 BIS Upgrade," *Indian Aviation*, October 1992.

Woodward, Sandy, *One Hundred Days: The Memoirs of the Falklands Battle Group Commander*, Annapolis: Naval Institute Press, 1992.

World Defense Almanac, 1991–1992, Baltimore: Military Publication Service, 1991.

World Weapon Database, Vol. 2, Soviet Military Aircraft, Lexington, MA: Heath, 1986.

Wright, Barton, *World Weapon Database, Vol. 1, Soviet Missiles*, Lexington, MA: Heath, 1986.

Yonay, Ehud, *No Margin for Error: The Making of the Israeli Air Force*, New York: Pantheon Books, 1993.